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Casualty Estimation for Nuclear and Radiological Weapons

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About This Publication

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Executive Summary

This analysis seeks to "identify and illustrate the applicability of using current casualty estimation methodologies to develop planning parameters for tactical and terroristic threats of the use of radiation exposure devices (RED), radiation dispersal devices (RDD), and improvised nuclear devices (IND), as well as conventional nuclear weapons."[1]

This analysis describes exemplar nuclear and radiological weapon threats; the application of the North Atlantic Treaty Organization (NATO) chemical, biological, radiological, and nuclear (CBRN) casualty estimation methodology for specific nuclear and radiological scenarios; and the calculational models necessary for the estimation of the dose, dose rates, or insult levels from these weapons. In the planning process, casualty estimates may influence the course of action selected, the flow of personnel into the theater, or the amount and timing of the medical assets moved into the theater. Thus, this estimate will be of interest to the operational, personnel, and medical planners, and possibly others.

For illustrative purposes, the situation presented in this study is that a (notional) commander has asked his staff to plan an operation by a light infantry battalion task force (LIBN) against an enemy, or in an area, that poses a radiological or nuclear threat. The Intelligence Staff Officer has validated this threat, without providing specifics on the type, size, or means of delivery of the weapon. The medical planning staff refers to the NATO CBRN casualty estimation methodology in Study Draft 3 of Allied Medical Publication 7.5, *NATO Planning Guide for the Estimation of CBRN Casualties* (AMedP-7.5 SD.3)[2] on how to do this.

In this study, a yield of 10 kilotons (10KT) is used as the nuclear challenge. This is reasonably within the "tactical nuclear weapon" range, is in the range that might be developed for an IND, and corresponds to the yield of interest for national emergency response planning. The basic nuclear challenge is a 10KT ground burst (which can be regarded as an IND), with alternative analyses that include a 10KT low air burst.

The basic radiological challenge is an attack from an improvised radiological device comprised of a truck-borne high explosive intermingled with $1.11x10^5$ terabecquerels (TBq) of the radioisotope Cesium-137 (^{137}Cs) which is equivalent to the radioactivity

[1] Institute for Defense Analyses Project Order CA-6-3079 Amendment 5, "CBRN Casualty Estimation and Support to the Medical CBRN Defense Planning & Response Project," signed 14 November 2013, Subproject 3, p. 4.

[2] North Atlantic Treaty Organization (NATO), *AMedP-7.5(A): NATO Planning Guide for the Estimation of Chemical, Biological, Radiological, and Nuclear (CBRN) Casualties*, (Brussels: NATO, in development).

present in a large food irradiator facility, and constitutes about 34.5 kg of ^{137}Cs. To illustrate alternative casualty estimates, the analysis includes a 740 TBq (147 g) Strontium-90 (^{90}Sr) source; a 0.37 TBq (3 g) Americium-241 (^{241}Am) source; a 10 TBq (16 g) Plutonium-238 (^{238}Pu) source (all of these are typical of large commercial sources); and the fallout (residual radiation) resulting from the 10KT ground burst nuclear weapon.

A supplemental scenario is of a popular and highly visible public event that might be considered at risk of a terrorist attack with nuclear or radiological weapons. This scenario was used to estimate the impact of the radiological or nuclear events on civilian populations. The selected location was Washington, DC, with an added tourist population of 300,000 persons evenly distributed on the National Mall between the Lincoln Memorial and 3rd St., NW. The casualties for the civilian scenario were estimated without regard to the shielding factors that might have been afforded by buildings or structures.

Ultimately, all that is required by the NATO CBRN casualty estimation methodology for radiological or nuclear incidents is an estimate of how much radiation (whole body or cutaneous), static overpressure, and burn is experienced by each populated icon in the scenario. AMedP-7.5 allows the estimation of casualties without consideration of protection, with consideration of protection, and/or with consideration of medical treatment.

For the nuclear weapon threat against the LIBN, six different combinations of threat and courses of action were considered. The result, in every case, is that the LIBN is incapacitated. In the case with the least number of casualties (10KT low air burst with protection available), 684 of the 816 persons considered (84%) were casualties. As a result, this unit would no longer be combat effective. To succeed at this mission, additional courses of action (such as countermeasure missions, unit dispersal, and nuclear protective posture) should be considered to further mitigate the nuclear weapon effects on the battlefield, with the attendant operational, personnel, and medical planning considerations.

For the radiological weapon threat against the LIBN, five different radiological threats were considered. Operations in a relatively recent fallout area resulted in the unit incapacitated with 97% casualties. The ^{137}Cs RDD resulted in a marginally better outcome, of only 31% casualties, which would still result in the unit being operationally ineffective. The use of ^{90}Sr as the radioisotope of interest produced no casualties in the estimate, nor did excursions with ^{241}Am or ^{238}Pu.

For the nuclear and radiological threats against the civilian population, both the 10KT ground burst and the ^{137}Cs RDD resulted in an extreme number of casualties: 630,512 and 374,154, respectively. The ^{90}Sr RDD resulted in considerably fewer casualties (although 33,622 casualties is still significant) and the ^{238}Pu and ^{241}Am RDDs resulted in zero casualties.

For a 10KT nuclear weapon threat, in none of the LIBN cases does enough of the unit remain sufficiently effective to succeed in any operational mission. If necessary, countermeasure missions to suppress this threat should be pursued prior to the enemy use of a nuclear weapon. Further mitigations such as unit dispersal, heightened signal security, and use of scouts far forward should be considered. The personnel planner recommends that the commander consider withdrawing this unit and replacing it, *in toto*, after any of the casualty-producing nuclear or radiological events. The medical requirements resulting from these nuclear and radiological events exceed the capabilities of any single deployed Role 3 medical treatment facility and there are no effective medical countermeasures that could be put in place to mitigate the casualty estimates. The commander should consider moving medical treatment or evacuation assets to the theater to address this medical requirement.

The civilian population scenario is not specific to an operational military unit, but the military could credibly be called in to provide consequence management support in the response phase after the use of a nuclear or radiological device. With that mission, it is clear that providing medical care and basic shelter to hundreds of thousands of casualties would require more than could be available, even in the entire DOD health care system. The total number of military personnel that would likely be called upon to provide support could compromise operational readiness, at least for those capabilities required in response. The senior DOD leaders, both military and civilian, must carefully balance a clear need for medical and logistical support with the strong potential for compromising the military's ability to respond to other strategic requirements. The personnel recommendation that minimizes strategic risk is to prioritize response to Reserve Component and National Guard units proximate to the event. The medical recommendation is to initiate coordination to facilitate the activation of the National Disaster Medical System. The combined capacity available in the civilian, Department of Veterans Affairs, and DOD health care systems may not be sufficient to address this requirement, and the requirement to move this number of patients to the available facilities is also staggering. Available deployable military treatment facilities should be used to provide triage and stabilization prior to evacuation.

In conclusion, the NATO casualty estimation methodology proved capable of estimating the numbers, types, and timing of casualties in all scenarios. Depending upon the scenario, the casualty estimates varied from none to 100% of the population considered. In all cases in which casualties were present, the numbers of casualties were such that they posed a considerable, if not catastrophic, operational problem. The methodology provides a planner with the necessary figures to consider for tactical and terroristic threats of the use of radiological or nuclear weapons.

Contents

1. Introduction

In 2013, the U.S. Army Office of the Surgeon General (OTSG) asked the Institute for Defense Analyses (IDA) to "identify and illustrate the applicability of using current casualty estimation methodologies to develop planning parameters for tactical and terroristic threats of the use of radiation exposure devices (RED), radiation dispersal devices (RDD), and improvised nuclear devices (IND), as well as conventional nuclear weapons."[3] The North Atlantic Treaty Organization (NATO) chemical, biological, radiological, and nuclear (CBRN) casualty estimation methodology presented in Allied Medical Publication 8, *NATO Planning Guide for the Estimation of CBRN Casualties* (AMedP-8(C)),[4] as proposed for revision in AMedP-7.5[5], will be used. This analysis describes exemplar nuclear and radiological weapon threats, the calculational models necessary for the estimation of the dose, dose rates, or insult levels from these weapons, and the application of the NATO CBRN casualty estimation methodology for specific nuclear and radiological scenarios. The objective of this paper is to demonstrate the casualty estimates resulting from the use of the NATO CBRN casualty estimation methodology. In the planning process, casualty estimates may influence the course of action selected, the flow of personnel into the theater, or the amount and timing of the medical assets moved into the theater. Thus, these estimates will be of interest to operational, personnel, and medical planners.

This paper is organized roughly along the lines of the planning process. For illustrative purposes, the basic situation presented in this study is that a (notional) commander has asked his staff to plan an operation against an enemy, or in an area, that poses a radiological or nuclear threat. The intelligence staff officer has validated this threat, without providing specifics on the type, size, or means of delivery of the weapon. The medical planning staff is tasked with estimating how many casualties might result from this operation. They refer to the NATO CBRN casualty estimation methodology in AMedP-8 on how to do this. The NATO CBRN casualty estimation methodology consists of four broad steps:

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[3] Project Order CA-6-3079 Amendment 5, CBRN Casualty Estimation and Support to the Medical CBRN Defense Planning & Response Project, signed 14 November 2013, Subproject 3, p. 4.

[4] North Atlantic Treaty Organization (NATO), *AMedP-8(C): NATO Planning Guide for the Estimation of Chemical, Biological, Radiological, and Nuclear (CBRN) Casualties*, STANAG 2553 (Brussels: NATO, 2011).

[5] North Atlantic Treaty Organization (NATO), *AMedP-7.5(A): NATO Planning Guide for the Estimation of Chemical, Biological, Radiological, and Nuclear (CBRN) Casualties*, (Brussels: NATO, in development).

Step 1. Describe the scenario in which personnel are expected to be exposed to CBRN agents or effects. This is the arrangement of forces relative to the release of the CBRN agent. This includes groups of individuals sharing a common location over time, known in the methodology as an “icon.” Each icon is given a unique identifier and a set of attributes that modify the CBRN challenge, and that are used to estimate what fraction of the CBRN challenge will become the Effective CBRN challenge

Step 2. Estimate the “effective CBRN challenge,” which is the cumulative amount or degree of CBRN agent or effect that is estimated to actually affect an icon. Estimating the effective CBRN challenge starts with describing the “CBRN Challenge,” the time-varying cumulative amount or degree of CBRN agent or effect estimated to be present in the physical environment with which icons are interacting, over the time period of interest. Then each icon’s attributes are accounted for to modify the impact of the CBRN agent or effect.

Step 3. Estimate the casualties, by comparing the effective CBRN challenge against the casualty estimation parameters described in the NATO CBRN casualty estimation methodology:

Step 4. Integrate the casualty estimate into the course of action analyses in the military planning process.

The estimation of casualties focuses on deterministic, rather than stochastic, effects. Deterministic effects include *acute* effects, which may result from internal or external radiation exposure. The severity of these effects is directly related to the dosage (higher dose results in a stronger effect). Stochastic effects are long-term impacts whose likelihood increases with radiation exposure, but whose severity is independent of dose. Stochastic effects, which occur in time increments long after exposure, are important to consider when evaluating the overall hazard and impact of a radiological attack. Health impacts that manifest more than a few months after exposure are not considered operationally relevant.

2. Step 1: Describe the Scenario

To illustrate the radiological and nuclear casualty estimation methodology, two scenarios will be considered: operational military formations and domestic populations. The threat to overseas military facilities could be similar to the domestic scenario in that there are high concentrations of personnel in fixed facilities, but the impact of nuclear or radiological weapons may be mitigated by increased alert and detection capabilities in deployed locations/overseas bases.

A. Operational Unit Scenario

To estimate radiological or nuclear casualties, it is necessary to specify a scenario that defines the number of personnel to be considered, as well as their locations and vulnerability to the nuclear effects and radiological agents. The scenario used, designated Scenario 1, is a light infantry battalion task force (LIBN), the same as was used in AMedP-8(C), and is illustrated in Figure 1. The 816 personnel in the scenario are represented by 155 individual locations of interest ("icons"); it is an entirely notional force arranged as if to guard an airstrip (represented by the white space in the middle of the icons). A complete list of the icons, and their characteristics pertinent to radiological or nuclear casualty estimation, is provided at Appendix A. (Note that this is an "illustrative" scenario, and does not reflect any unit currently fielded by the U.S. military.) In addition to location and the number of associated individuals, icon descriptions also include information that can be used to estimate the vulnerability of its individuals to CBRN exposure of the type postulated in the scenario. This vulnerability is determined by exposure factors—the fraction of ambient agent an individual inhales, absorbs, or otherwise exposes himself to—and shielding factors—passive characteristics of the individuals associated with a given icon, such as their location within buildings of various types, which may serve to limit agent exposure. In the illustrative scenario, both exposure and shielding factors are considered constant over time. The casualties for the military scenario were estimated without regard to the civilian population that might be in the location of the radiological or nuclear event.

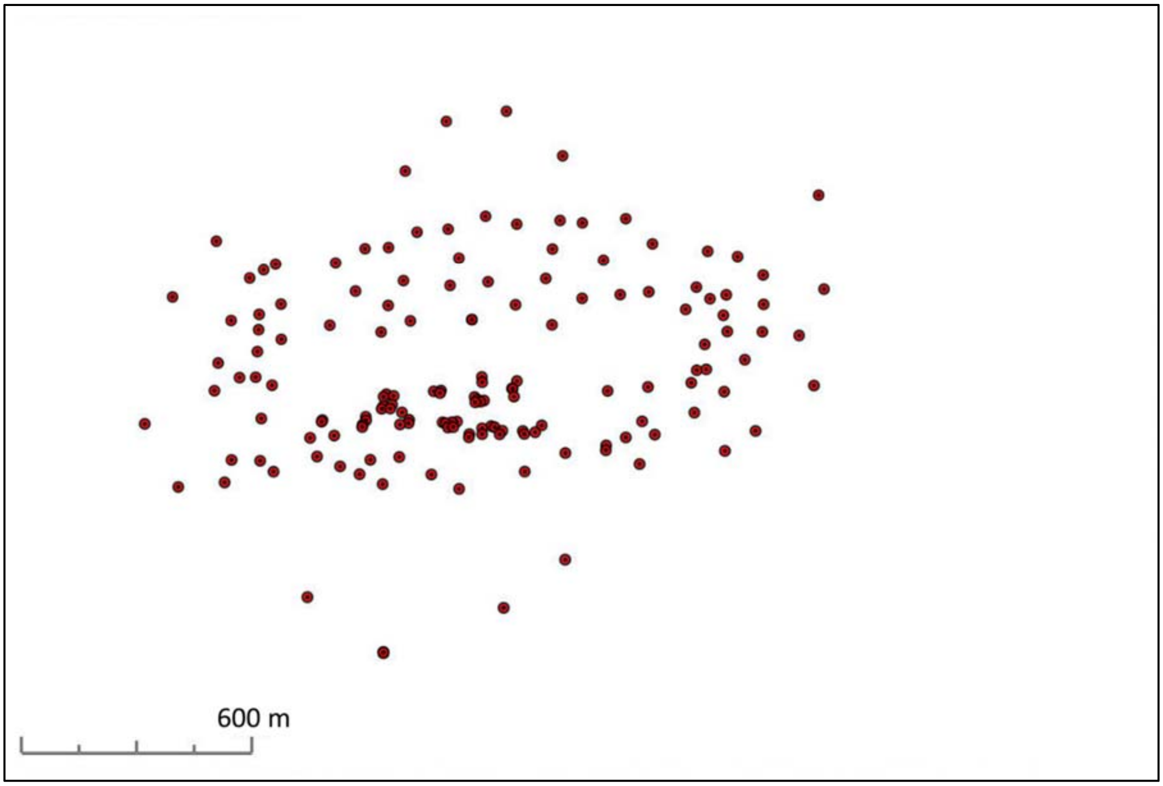

Figure 1: Layout of Icons

B. The Domestic Scenario

To estimate the impact of the radiological or nuclear events on civilian populations, it was necessary to select a location for which there was available civilian population data. The location was selected to reflect detailed population models (three arc-second resolution, about 100m squares) and to include a popular and highly visible public event that might be considered at risk of a terrorist attack using nuclear or radiological weapons. The selected location was Washington, DC, with an added tourist population of 300,000 persons evenly distributed on the National Mall between the Lincoln Memorial and Third Street, NW. The casualties for the civilian scenario, designated Scenario 2, were estimated without regard to the shielding factors that might have been afforded by buildings or structures.

C. Protection and Medical Care

The NATO casualty estimation methodology allows the planner to consider whether or not physical protection is available and what level of medical care can be provided. Medical care can include supportive care, medical treatment that is specific to the injuries or illnesses from exposure to the CBRN agents or effects and, in the case of radiological injuries, whether or not granulocyte-colony stimulating factor (G-CSF) treatment is

administered. Medical care is assumed to be appropriate to the injuries received. For acute radiation injury, this is basically supportive medical care to treat the symptoms of the injury and make the patient more comfortable. Recently, G-CSF was approved as a specific treatment for acute radiation injury. AMedP-7.5 allows for consideration of medical care with and without G-CSF.

Table 1 illustrates the different combinations of population, challenge, protection, and medical treatment that are considered in the different scenarios in this analysis. Note that this is not all possible combinations of challenge, protection, and treatment, but it is a limited subset for illustrative purposes. The scenarios are designated to differentiate the combinations included. “N” indicates a nuclear weapon (10 kilotons (10KT) in this case), while “*xx*RDD” indicates a radiological weapon, with “*xx*” being the radioisotope considered. For the nuclear weapon challenge, “Grd” and “Air” indicate a ground burst or low air burst, respectively. “0” indicates no protection is considered, while “P” indicates protection is considered but not medical care. “M” indicates physical protection and the administration of medical care are considered, but not the administration of G-CSF. “G” indicates physical protection and the administration of medical care with G-CSF are considered.

Table 1. Nuclear and Radiological Scenarios

Scenario	Population Considered	Challenge	Protection Available	Medical Treatment Provided	G-CSF Administered
1-N-Grd-0	LIBN	10KT-Ground Burst	No	No	No
1-N-Grd-P	LIBN	10KT-Ground Burst	Yes	No	No
1-N-Grd-M	LIBN	10KT-Ground Burst	Yes	Yes	No
1-N-Grd-G	LIBN	10KT-Ground Burst	Yes	Yes	Yes
1-N-Air-0	LIBN	10KT-Air Burst	No	No	No
1-N-Air-G	LIBN	10KT-Air Burst	Yes	Yes	Yes
2-N-Grd-0	Civilian	10KT-Ground Burst	No	No	No
1-CsRDD-0	LIBN	^{137}Cs RDD	No	No	No
1-SrRDD-0	LIBN	^{90}Sr RDD	No	No	No
1-AmRDD-0	LIBN	^{241}Am RDD	No	No	No
1-PuRDD-0	LIBN	^{238}Pu RDD	No	No	No
2-CsRDD-0	Civilian	^{137}Cs RDD	No	No	No
1-Fallout-0	LIBN	Residual Radiation	No	No	No

3. Step 2: Estimate the Effective Nuclear/ Radiological Challenge

In the planning process, staff officers would rely on an intelligence estimate to identify the radiological and nuclear threats, and these would be translated into the radiological and nuclear challenges for casualty estimation. If the planning staff does not have the capability to estimate the effective CBRN challenge (and most do not), the staff can “reach back” to the Defense Threat Reduction Agency (DTRA) or other agencies that have this capability. Appendix B describes some of the technical questions and modelling that must be addressed to estimate the effective radiological or nuclear challenge. For this analysis, it is assumed that an intelligence estimate does not include specific characteristics of the radiological and nuclear threat, such as yield, delivery system, or type of isotope. This forces the planners to make assumptions about the specific type of weapon and the resulting challenge.

A. Effective Nuclear Weapon Challenge

For this analysis, the task specified both nuclear weapons and improvised nuclear devices (INDs). From a casualty estimation perspective, there is little difference, except that the expected yields and heights of burst are more limited for an IND. A yield of 10KT is used in the example scenario. This is reasonably within the “tactical nuclear weapon” range, is in the range that might be developed for an IND, and corresponds to the yield of interest for national emergency response planning.[6] Two different heights of burst (HoB) will be used to compare the estimated casualties:

1. HoB = 1m, as an example surface (or “ground”) burst;
2. HoB = 129m, as an example of an “optimized” low air burst for comparison, corresponding to HoB = $60W^{1/3}$.

1. Effective Nuclear Weapon Challenge – Scenario 1-N-Grd-0: 10 KT, Ground Burst, LIBN, All Personnel Unprotected, No Medical Treatment Considered

Figure 2 illustrates the magnitude of the radiation, blast, and thermal energies for a 10KT ground burst on the operational unit scenario, an LIBN task force.

[6] U.S. Department of Homeland Security, Federal Emergency Management Agency (FEMA), *Planning Guidance for Response to a Nuclear Detonation*, Second Edition, June 2010, p. 9.

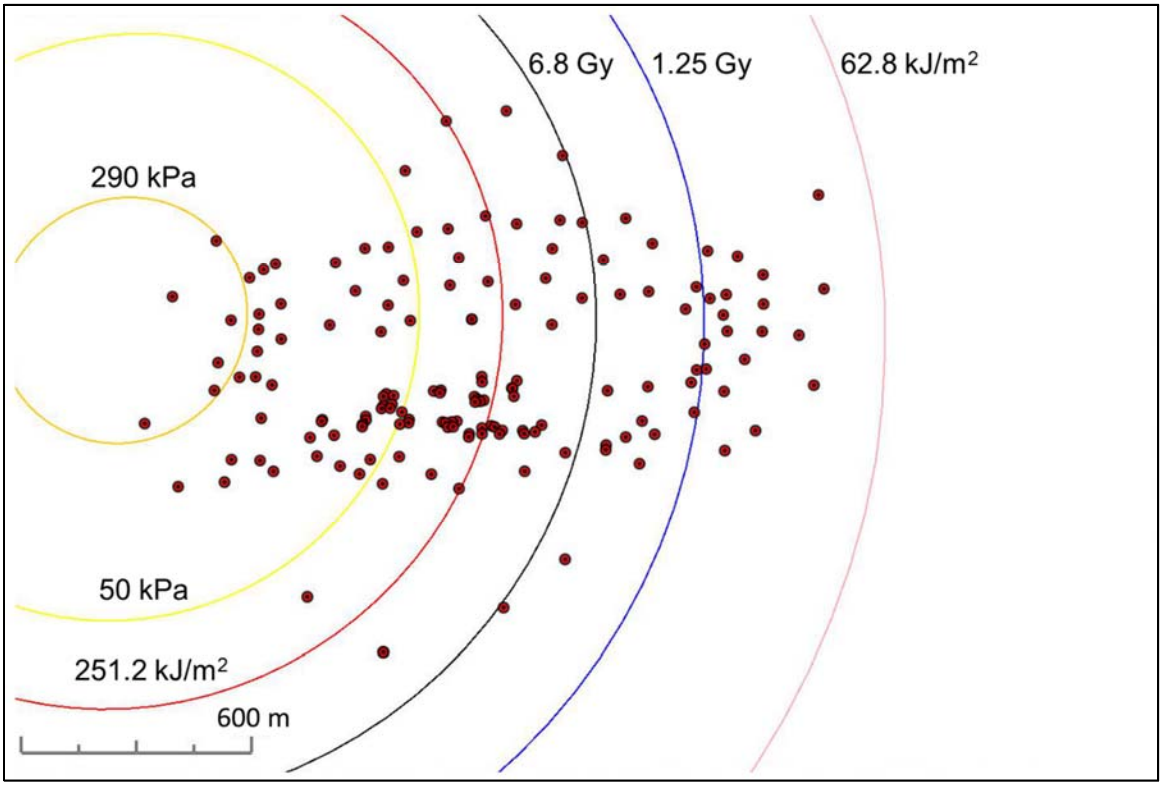

Figure 2. 10KT Ground Burst on Task Force

Table 2 provides the effective nuclear weapon challenge estimated for the personnel in the LIBN. The cells in this table are defined by the dose bands for radiation (R), blast static overpressure (B) and thermal exposures (T) as described in AMedP-7.5. (Appendix E includes the tables from AMedP-7.5 that define the dose bands for each casualty type.) The upper left cell (R:<125cGy, B:<50kPa, T:<1% body surface area (BSA)) enumerates the personnel unaffected by the prompt effects – in this case, none.

Table 2. Effective Nuclear Weapon Challenge, 10 KT, Ground Burst, LIBN, All Personnel Unprotected

CHALLENGE:	T: <1% BSA	T: 1%-10% BSA	T: 10%-20% BSA	T: 20%-30% BSA	T: > 30% BSA
R:<125cGy / B:<50kPa	0	131	0	0	0
R:125-300cGy / B:<50kPa	0	72	0	0	0
R:300-450cGy / B:<50kPa	0	23	0	0	0
R:450-830cGy / B:<50kPa	0	41	0	0	0
R:>830cGy / B:<50kPa	0	19	70	82	116
R:<125cGy / B:50-140kPa	0	0	0	0	0
R:125-300cGy / B:50-140kPa	0	0	0	0	0

CHALLENGE:	T: <1% BSA	T: 1%-10% BSA	T: 10%-20% BSA	T: 20%-30% BSA	T: > 30% BSA
R:300-450cGy / B:50-140kPa	0	0	0	0	0
R:450-830cGy / B:50-140kPa	0	0	0	0	0
R:>830cGy / B:50-140kPa	0	0	0	0	163
R:<125cGy / B:140-240kPa	0	0	0	0	0
R:125-300cGy / B:140-240kPa	0	0	0	0	0
R:300-450cGy / B:140-240kPa	0	0	0	0	0
R:450-830cGy / B:140-240kPa	0	0	0	0	0
R:>830cGy / B:140-240kPa	0	0	0	0	74
R:<125cGy / B:240-290kPa	0	0	0	0	0
R:125-300cGy / B:240-290kPa	0	0	0	0	0
R:300-450cGy / B:240-290kPa	0	0	0	0	0
R:450-830cGy / B:240-290kPa	0	0	0	0	0
R:>830cGy / B:240-290kPa	0	0	0	0	4
R:<125cGy / B:>290kPa	0	0	0	0	0
R:125-300cGy / B:>290kPa	0	0	0	0	0
R:300-450cGy / B:>290kPa	0	0	0	0	0
R:450-830cGy / B:>290kPa	0	0	0	0	0
R:>830cGy / B:>290kPa	0	0	0	0	21

2. Effective Nuclear Weapon Challenge – Scenario 1-N-Grd-P: 10 KT, Ground Burst, LIBN, All Personnel Protected, No Medical Treatment Considered

In order to consider the protection provided by vehicles, structures, or emplacements, the same nuclear incident scenario can be used, but modified to include protection factors associated with each icon in the scenario. AMedP-7.5 suggests radiation shielding protection factors[7] and thermal transmission values.[8] Blast static overpressure protection is not modeled; the suggested value for the blast shielding protection factor in AMedP-7.5 is "1."[9] These factors are included in the unit description in Appendix A. Table 3 provides the effective nuclear weapon challenge estimated for the personnel in the LIBN when protection factors are considered. The upper left cell (R:<125cGy, B:<50kPa, T:<1%BSA) enumerates the personnel unaffected by the prompt effects – in this case, 71. Note that considering protection had a considerable influence on the distribution of burns: 330 personnel were without significant burns (in the first column, "T<1%BSA) where

[7] AMedP-7.5, SD.3, Working Copy, Table 2-7, 26 October 2015, 2-10.

[8] AMedP-7.5, SD.3, Working Copy, Table 4-47, 26 October 2015, 4-70.

[9] AMedP-7.5, SD.3, Working Copy, Table 2-8, 26 October 2015, 2-10.

previously all unit personnel had been burned. The impact of radiation protection was less striking, with 33 personnel moved into the lowest dose range (R:<125cGy) but only 7 personnel moved out of the dose ranges and died of wounds (DOW) (R:450-830cGy and R:>830cGy).

Table 3. Effective Nuclear Weapon Challenge, 10 KT, Ground Burst, LIBN, All Personnel Protected

CHALLENGE:	T: <1% BSA	T: 1%-10% BSA	T: 10%-20% BSA	T: 20%-30% BSA	T: > 30% BSA
R:<125cGy / B:<50kPa	71	94	0	0	0
R:125-300cGy / B:<50kPa	9	47	0	0	0
R:300-450cGy / B:<50kPa	7	7	0	0	0
R:450-830cGy / B:<50kPa	7	41	0	2	0
R:>830cGy / B:<50kPa	123	16	57	33	43
R:<125cGy / B:50-140kPa	0	0	0	0	0
R:125-300cGy / B:50-140kPa	0	0	0	0	0
R:300-450cGy / B:50-140kPa	0	0	0	0	0
R:450-830cGy / B:50-140kPa	0	0	0	0	0
R:>830cGy / B:50-140kPa	64	0	0	0	99
R:<125cGy / B:140-240kPa	0	0	0	0	0
R:125-300cGy / B:140-240kPa	0	0	0	0	0
R:300-450cGy / B:140-240kPa	0	0	0	0	0
R:450-830cGy / B:140-240kPa	0	0	0	0	0
R:>830cGy / B:140-240kPa	50	0	0	0	24
R:<125cGy / B:240-290kPa	0	0	0	0	0
R:125-300cGy / B:240-290kPa	0	0	0	0	0
R:300-450cGy / B:240-290kPa	0	0	0	0	0
R:450-830cGy / B:240-290kPa	0	0	0	0	0
R:>830cGy / B:240-290kPa	1	0	0	0	3
R:<125cGy / B:>290kPa	0	0	0	0	0
R:125-300cGy / B:>290kPa	0	0	0	0	0
R:300-450cGy / B:>290kPa	0	0	0	0	0
R:450-830cGy / B:>290kPa	0	0	0	0	0
R:>830cGy / B:>290kPa	0	0	0	0	21

3. Effective Nuclear Weapon Challenge – Scenario 1-N-Grd-M: 10 KT, Ground Burst, LIBN, All Personnel Protected, Medical Treatment Considered

The same nuclear incident scenario can be used to consider the impact of medical care on the casualty estimate, but the injury profiles (severity over time) must be modified to account for medical care. Consideration of medical care does not change the amount of exposure to any agent or effect, but does change the outcome of that exposure. AMedP-7.5 (see Appendix E) provides instructions for modifying the outcomes of exposure to whole body radiation, blast static overpressure, and thermal fluence, respectively. Note that the dose ranges considered without medical treatment are modified in AMedP-7.5 for Whole Body Radiation and Thermal Fluence, and that results in a modification of the ranges considered in the effective challenge tables. Table 4 illustrates the effective nuclear weapon challenge estimated for LIBN personnel with consideration of protection, and the ranges of those exposures appropriate to the consideration of medical care.

Table 4. Effective Nuclear Weapon Challenge, 10 KT, Ground Burst, LIBN, All Personnel Protected, Minimal Medical Treatment Considered

CHALLENGE:	T: <1% BSA	T: 1%-10% BSA	T: 10%-15% BSA	T: 15%-20% BSA	T: 20%-30% BSA	T: 30%-45% BSA	T: >45% BSA
R:<125cGy / B:<50kPa	71	94	0	0	0	0	0
R:125-300cGy / B:<50kPa	9	47	0	0	0	0	0
R:300-450cGy / B:<50kPa	7	7	0	0	0	0	0
R:450-680cGy / B:<50kPa	7	34	0	0	2	0	0
R:680-830cGy / B:<50kPa	0	7	0	0	0	0	0
R:830-850cGy / B:<50kPa	0	0	0	0	0	0	0
R:>850cGy / B:<50kPa	123	16	22	36	33	43	0
R:<125cGy / B:50-140kPa	0	0	0	0	0	0	0
R:125-300cGy / B:50-140kPa	0	0	0	0	0	0	0
R:300-450cGy / B:50-140kPa	0	0	0	0	0	0	0
R:450-680cGy / B:50-140kPa	0	0	0	0	0	0	0
R:680-830cGy / B:50-140kPa	0	0	0	0	0	0	0
R:830-850cGy / B:50-140kPa	0	0	0	0	0	0	0
R:>850cGy / B:50-140kPa	64	0	0	0	0	85	14
R:<125cGy / B:140-240kPa	0	0	0	0	0	0	0
R:125-300cGy / B:140-240kPa	0	0	0	0	0	0	0
R:300-450cGy / B:140-240kPa	0	0	0	0	0	0	0
R:450-680cGy / B:140-240kPa	0	0	0	0	0	0	0
R:680-830cGy / B:140-240kPa	0	0	0	0	0	0	0
R:830-850cGy / B:140-240kPa	0	0	0	0	0	0	0
R:>850cGy / B:140-240kPa	50	0	0	0	0	0	24

CHALLENGE:	T: <1% BSA	T: 1%-10% BSA	T: 10%-15% BSA	T: 15%-20% BSA	T: 20%-30% BSA	T: 30%-45% BSA	T: >45% BSA
R:<125cGy / B:240-290kPa	0	0	0	0	0	0	0
R:125-300cGy / B:240-290kPa	0	0	0	0	0	0	0
R:300-450cGy / B:240-290kPa	0	0	0	0	0	0	0
R:450-680cGy / B:240-290kPa	0	0	0	0	0	0	0
R:680-830cGy / B:240-290kPa	0	0	0	0	0	0	0
R:830-850cGy / B:240-290kPa	0	0	0	0	0	0	0
R:>850cGy / B:240-290kPa	1	0	0	0	0	0	3
R:<125cGy / B:>290kPa	0	0	0	0	0	0	0
R:125-300cGy / B:>290kPa	0	0	0	0	0	0	0
R:300-450cGy / B:>290kPa	0	0	0	0	0	0	0
R:450-680cGy / B:>290kPa	0	0	0	0	0	0	0
R:680-830cGy / B:>290kPa	0	0	0	0	0	0	0
R:830-850cGy / B:>290kPa	0	0	0	0	0	0	0
R:>850cGy / B:>290kPa	0	0	0	0	0	0	21

4. Effective Nuclear Weapon Challenge – Scenario 2-N-0: 10 KT, Ground Burst, Civilian Population, All Personnel Unprotected and Without Medical Treatment

The civilian population scenario is included as an illustration of the casualty estimation process as it might be used for planning a response to a domestic incident. This scenario could be regarded as a “National Security Special Event,” where a large number of people are attending an event in the middle of a city. In this case, there are 300,000 people (“tourists”) in the park-like area in the center of the city in addition to the population of the city. Because large metropolitan areas extend beyond the range of effects of a 10KT nuclear weapon (or IND), only people within 5 km of the detonation are considered. In this scenario, protection is not considered, as there is no capability to estimate what protection would be available to a large civilian population pursuing diverse activities both indoors and outside. Medical care is not considered, although it could be. Given the number and extent of casualties, it is difficult to imagine being able to collect, transport, triage, and treat the estimated number of casualties without significantly adjusting the method of delivery and type of care available.

The civilian population scenario considers 1,116,207 persons (300,000 “tourists” and 816,207 “residents”) distributed at 17,497 different locations in a roughly circular area 5 km in diameter. The 300,000 persons are distributed evenly in 11,943 separate 10 m squares in the (approximately rectangular) notional event area, and 816,207 are distributed in 5,554 separate areas, each approximately 1 km square, consistent with the estimated

population of the metropolitan area. The point of detonation of the nuclear weapon (ground zero) is adjacent (less than 20 m) from one edge of the event area. Table 5 provides the effective nuclear weapon challenge estimated for the civilian personnel. The upper left cell (R:<125cGy, B:<50kPa, T: <1% BSA) enumerates the personnel unaffected by the prompt effects – in this case, 485,695, or about 44% of the considered population.

Table 5. Effective Nuclear Weapon Challenge, 10 KT, Ground Burst, Civilian Population, All Personnel Unprotected and without Medical Treatment

CHALLENGE:	T: <1% BSA	T: 1%-10% BSA	T: 10%-20% BSA	T: 20%-30% BSA	T: > 30% BSA
R:<125cGy / B:<50kPa	485,695	179,466	0	0	0
R:125-300cGy / B:<50kPa	0	49,511	0	0	0
R:300-450cGy / B:<50kPa	0	17,395	0	0	0
R:450-830cGy / B:<50kPa	0	34,080	0	0	0
R:>830cGy / B:<50kPa	0	9,776	30,813	52,484	58,997
R:<125cGy / B:50-140kPa	0	0	0	0	0
R:125-300cGy / B:50-140kPa	0	0	0	0	0
R:300-450cGy / B:50-140kPa	0	0	0	0	0
R:450-830cGy / B:50-140kPa	0	0	0	0	0
R:>830cGy / B:50-140kPa	0	0	0	0	105,696
R:<125cGy / B:140-240kPa	0	0	0	0	0
R:125-300cGy / B:140-240kPa	0	0	0	0	0
R:300-450cGy / B:140-240kPa	0	0	0	0	0
R:450-830cGy / B:140-240kPa	0	0	0	0	0
R:>830cGy / B:140-240kPa	0	0	0	0	34,338
R:<125cGy / B:240-290kPa	0	0	0	0	0
R:125-300cGy / B:240-290kPa	0	0	0	0	0
R:300-450cGy / B:240-290kPa	0	0	0	0	0
R:450-830cGy / B:240-290kPa	0	0	0	0	0
R:>830cGy / B:240-290kPa	0	0	0	0	9,332
R:<125cGy / B:>290kPa	0	0	0	0	0
R:125-300cGy / B:>290kPa	0	0	0	0	0
R:300-450cGy / B:>290kPa	0	0	0	0	0
R:450-830cGy / B:>290kPa	0	0	0	0	0
R:>830cGy / B:>290kPa	0	0	0	0	48,623

5. Effective Nuclear Weapon Challenge – Scenario 1-N-Air-0: 10 KT, Low Air Burst (HoB = 129m), LIBN, All Personnel Unprotected and without Medical Treatment

A variation of the nuclear casualty scenarios considered above is to change the height of burst of the weapon from the ground surface to an altitude that increases the range of blast and thermal effects. This could be considered a military attack with a more sophisticated nuclear weapon that includes fusing to control the detonation at a specific altitude. Rather than consider all permutations of protection and medical care, the first case will be without consideration of protection. This is equivalent to all of the unit personnel standing in the open, out of their vehicles, buildings, or emplacements. The protection afforded by the uniform is considered, though, to estimate the severity of burns resulting from exposure to the thermal fluence from the nuclear detonation. Table 6 provides the effective nuclear weapon challenge estimated for the personnel in the LIBN. Note that with a 129m HoB, compared to a surface burst, the significant change is that all personnel receive severe burns (in the rightmost column, T>30%BSA), rather than an even distribution across most of the thermal exposure columns.

Table 6. Effective Nuclear Weapon Challenge, 10 KT, Low Air Burst (HoB = 129m), LIBN, All Personnel Unprotected

CHALLENGE:	T: <1% BSA	T: 1%-10% BSA	T: 10%-20% BSA	T: 20%-30% BSA	T: > 30% BSA
R:<125cGy / B:<50kPa	0	0	0	0	97
R:125-300cGy / B:<50kPa	0	0	0	0	71
R:300-450cGy / B:<50kPa	0	0	0	0	35
R:450-830cGy / B:<50kPa	0	0	0	0	50
R:>830cGy / B:<50kPa	0	0	0	0	268
R:<125cGy / B:50-140kPa	0	0	0	0	0
R:125-300cGy / B:50-140kPa	0	0	0	0	0
R:300-450cGy / B:50-140kPa	0	0	0	0	0
R:450-830cGy / B:50-140kPa	0	0	0	0	0
R:>830cGy / B:50-140kPa	0	0	0	0	194
R:<125cGy / B:140-240kPa	0	0	0	0	0
R:125-300cGy / B:140-240kPa	0	0	0	0	0
R:300-450cGy / B:140-240kPa	0	0	0	0	0
R:450-830cGy / B:140-240kPa	0	0	0	0	0
R:>830cGy / B:140-240kPa	0	0	0	0	76
R:<125cGy / B:240-290kPa	0	0	0	0	0
R:125-300cGy / B:240-290kPa	0	0	0	0	0
R:300-450cGy / B:240-290kPa	0	0	0	0	0

CHALLENGE:	T: <1% BSA	T: 1%-10% BSA	T: 10%-20% BSA	T: 20%-30% BSA	T: > 30% BSA
R:450-830cGy / B:240-290kPa	0	0	0	0	0
R:>830cGy / B:240-290kPa	0	0	0	0	11
R:<125cGy / B:>290kPa	0	0	0	0	0
R:125-300cGy / B:>290kPa	0	0	0	0	0
R:300-450cGy / B:>290kPa	0	0	0	0	0
R:450-830cGy / B:>290kPa	0	0	0	0	0
R:>830cGy / B:>290kPa	0	0	0	0	14

6. Effective Nuclear Weapon Challenge – Scenario 1-N-Air-G: 10 KT, Low Air Burst (HoB = 129m), LIBN, All Personnel Protected, Medical Treatment Considered

The final permutation in the nuclear casualty scenario in this study considers the impact of protection and medical treatment with G-CSF. Table 7 provides the effective nuclear weapon challenge estimated for the personnel in the LIBN. Considering protection moves personnel out of the highest thermal exposure range and to the range of thermally unexposed (T<1%BSA), as well as shifts some personnel into lower radiation dose ranges. The additional consideration of G-CSF changes the dose range for DOW and allows personnel who have received up to 8.5 Gy of whole body radiation to become convalescent instead of DOW.

Table 7. Effective Nuclear Weapon Challenge, 10 KT, Low Air Burst (HoB = 129m), LIBN, All Personnel Protected, Medical Treatment Considered

CHALLENGE:	T: <1% BSA	T: 1%-10% BSA	T: 10%-15% BSA	T: 15%-20% BSA	T: 20%-30% BSA	T: 30%-45% BSA	T: >45% BSA
R:<125cGy / B:<50kPa	54	0	0	0	0	0	59
R:125-300cGy / B:<50kPa	24	0	0	0	0	0	49
R:300-450cGy / B:<50kPa	1	0	0	0	0	0	32
R:450-680cGy / B:<50kPa	9	0	0	0	0	0	25
R:680-830cGy / B:<50kPa	2	0	0	0	0	0	8
R:830-850cGy / B:<50kPa	0	0	0	0	0	0	0
R:>850cGy / B:<50kPa	107	0	0	0	0	0	152
R:<125cGy / B:50-140kPa	0	0	0	0	0	0	0
R:125-300cGy / B:50-140kPa	0	0	0	0	0	0	0
R:300-450cGy / B:50-140kPa	0	0	0	0	0	0	0
R:450-680cGy / B:50-140kPa	0	0	0	0	0	0	0
R:680-830cGy / B:50-140kPa	0	0	0	0	0	0	0

CHALLENGE:	T: <1% BSA	T: 1%-10% BSA	T: 10%-15% BSA	T: 15%-20% BSA	T: 20%-30% BSA	T: 30%-45% BSA	T: >45% BSA
R:830-850cGy / B:50-140kPa	0	0	0	0	0	0	0
R:>850cGy / B:50-140kPa	83	0	0	0	0	0	111
R:<125cGy / B:140-240kPa	0	0	0	0	0	0	0
R:125-300cGy / B:140-240kPa	0	0	0	0	0	0	0
R:300-450cGy / B:140-240kPa	0	0	0	0	0	0	0
R:450-680cGy / B:140-240kPa	0	0	0	0	0	0	0
R:680-830cGy / B:140-240kPa	0	0	0	0	0	0	0
R:830-850cGy / B:140-240kPa	0	0	0	0	0	0	0
R:>850cGy / B:140-240kPa	50	0	0	0	0	0	26
R:<125cGy / B:240-290kPa	0	0	0	0	0	0	0
R:125-300cGy / B:240-290kPa	0	0	0	0	0	0	0
R:300-450cGy / B:240-290kPa	0	0	0	0	0	0	0
R:450-680cGy / B:240-290kPa	0	0	0	0	0	0	0
R:680-830cGy / B:240-290kPa	0	0	0	0	0	0	0
R:830-850cGy / B:240-290kPa	0	0	0	0	0	0	0
R:>850cGy / B:240-290kPa	1	0	0	0	0	0	10
R:<125cGy / B:>290kPa	0	0	0	0	0	0	0
R:125-300cGy / B:>290kPa	0	0	0	0	0	0	0
R:300-450cGy / B:>290kPa	0	0	0	0	0	0	0
R:450-680cGy / B:>290kPa	0	0	0	0	0	0	0
R:680-830cGy / B:>290kPa	0	0	0	0	0	0	0
R:830-850cGy / B:>290kPa	0	0	0	0	0	0	0
R:>850cGy / B:>290kPa	0	0	0	0	0	0	14

B. Effective Radiological Weapon Challenge

The radiological challenge, similar to that presented in the AMedP-7.5 Illustrative Examples,[10] is an attack from an improvised radiological device comprised of a truck-borne high explosive intermingled with 1.11×10^5 terabecquerels (TBq) of the radioisotope Cesium-137 (^{137}Cs) in the vicinity of the LIBN. (This is equivalent to the radioactivity present in a large food irradiator facility, and constitutes about 34.5 kg of ^{137}Cs.) To illustrate alternative casualty estimates, the current analysis includes a 740 TBq (147 g) Strontium-90 (^{90}Sr) source; a 0.37 TBq (3 g) Americium-241 (^{241}Am) source; a 10 TBq (16 g) Plutonium-238 (^{238}Pu) source (all of these are typical of large commercial sources), and the fallout (residual radiation) resulting from the 10KT ground burst nuclear weapon

[10] AMedP-7.5, SD.3, Working Copy, 26 October 2015, A-31.

in the vicinity of the LIBN (see Table 8). The different isotopes and amounts allow for consideration of radiological weapon effects with different radiations and activities.

Table 8. Isotopes Considered as Potential Radiological Weapons

Isotope	Symbol	Activity (TBq)	Mass (kg)	Radiation	Source	Form
Cesium-137	^{137}Cs	$1.11x10^5$	34.5	β and γ	Irradiators: sterilization and food preservation	Pressed Powder
Strontium-90	^{90}Sr	740	0.147	β	Radioisotopic thermoelectric generators (RTGs)	Metal Oxide Ceramic
Americium-241	^{241}Am	0.37	0.003	α and γ	Well logging	Pressed ceramic powder (oxide)
Plutonium-238	^{238}Pu	10	0.016	α	Radioisotopic thermoelectric generators (RTGs)	Metal Oxide Ceramic

1. Effective Radiological Weapon Challenge – Scenario 1-CsRDD-0: ^{137}Cs RDD, LIBN, All Personnel Unprotected

The LIBN is as described for the nuclear scenario: 816 personnel distributed at 155 locations in a roughly oval shaped area 2 km long and 1 km wide (with some personnel at locations as much as 200 m to either side). The point of detonation of the RDD is less than 200 m from the nearest unit personnel. The radioisotope source modeled in the RDD is $1.11x10^5$ TBq (34.5 kg) of ^{137}Cs. Figure 3 illustrates the magnitude of the radioactive material that would be released over the LIBN task force in this scenario. Table 9 provides the effective radiological weapon challenge estimated for the personnel in the LIBN. The cells in this table are defined by the dose bands for whole body (WB) and cutaneous (CUT) radiation as described in AMedP-7.5 (see Appendix E). The upper left cell (WB Rad: <125cGy, CUT Rad: <200cGy) enumerates the personnel unaffected by the whole body and/or cutaneous radiation – in this case, 565, or 69% of the unit.

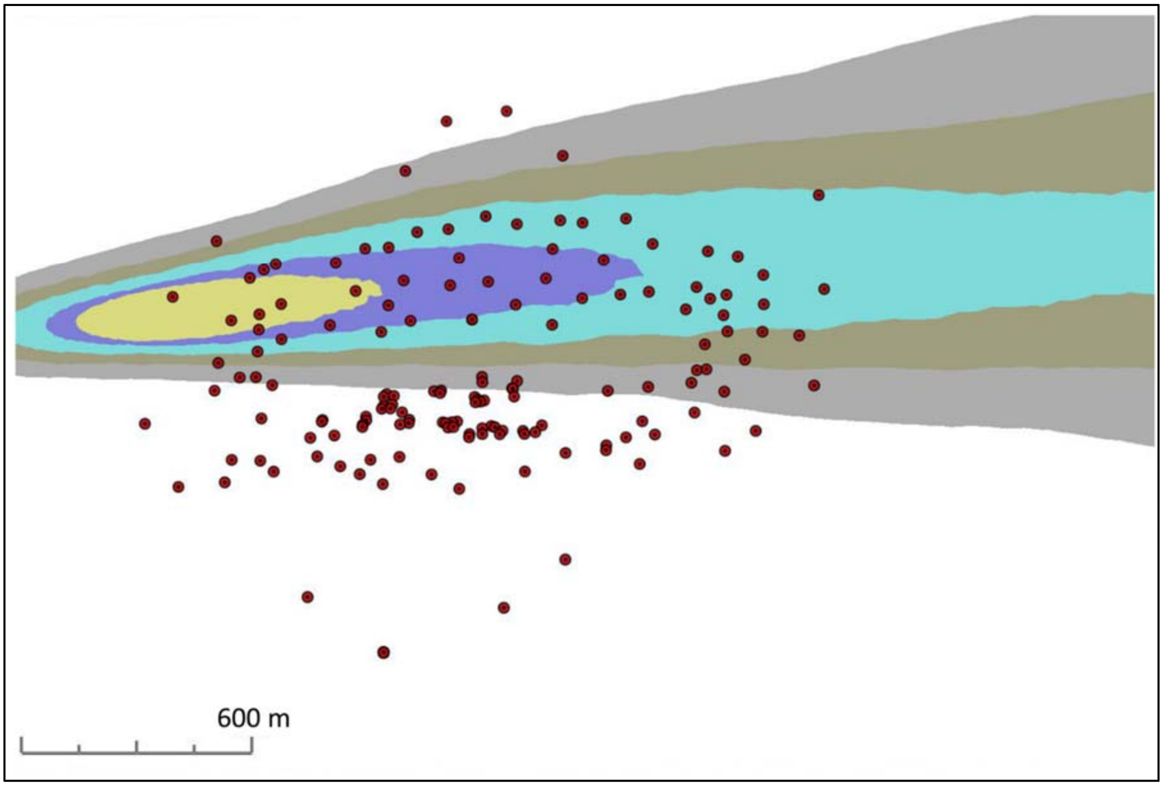

Figure 3: ^{137}Cs RDD Attack on Task Force

Table 9. Effective Radiological Weapon Challenge, ^{137}Cs RDD, LIBN, All Personnel Unprotected

	Cutaneous Radiation				
CHALLENGE	**CUT Rad: <200cGy**	**CUT Rad: 200-1500cGy**	**CUT Rad: 1500-4000cGy**	**CUT Rad: 4000-55000cGy**	**CUT Rad: >55000cGy**
WB Rad: <125cGy	565	223	21	0	0
WB Rad: 125-300cGy	0	0	0	7	0
WB Rad: 300-450cGy	0	0	0	0	0
WB Rad: 450-830cGy	0	0	0	0	0
WB Rad: >830cGy	0	0	0	0	0

2. Effective Radiological Weapon Challenge – Scenario 2-CsRDD-0: ^{137}Cs RDD, Civilian Population, All Personnel Unprotected and without Medical Treatment

The civilian population scenario illustrates the casualty estimation process as it may be used for planning a response to a domestic incident. This scenario may be regarded as a "national security special event," in which a large number of people are attending in the middle of a city. In this case, there are 300,000 people ("tourists") in the park-like area in the center of the city in addition to the city population. Because large metropolitan areas extend beyond the range of effects of a 10KT nuclear weapon (or IND), only people within 5 km of the detonation are considered. In this scenario, protection is not considered, as there is no capability to estimate what protection would be available to a large civilian population pursuing diverse activities both indoors and outside. Medical care is not considered, although it could be. Given the number and extent of casualties, it is difficult to imagine being able to collect, transport, triage, and treat the estimated number of casualties without significantly adjusting the method of delivery and type of care available.

There are 4,503,258 personnel (300,000 "tourists" and 4,203,258 "residents") in the civilian population scenario, distributed at 215,953 different locations in a 45^{o} arc with a roughly circular base area 5 km in diameter. The 300,000 persons are distributed evenly in 11,943 separate 10 m squares in the (approximately rectangular) notional event area; 816,207 are distributed in 5,554 separate areas, each approximately 1 km square, within 5 km of the release, and the remainder are in 198,456 approximately 1 km squares in the 45^{o} downwind arc. The 5 km circle and the downwind arc are populated according to the estimated population of the metropolitan area. All personnel are assumed to be breathing at a rate of 0.015 m^3/min. The point of detonation of the ^{137}Cs RDD is adjacent (less than 20 m) from one edge of the event area. Table 10 provides the effective radiological weapon challenge estimated for the civilian personnel. The upper left cell (WB Rad: <125cGy, CUT Rad: <200cGy) enumerates the personnel unaffected by the whole body and/or cutaneous radiation – in this case, 4,128,104, or 92% of the considered population.

Table 10. Effective Radiological Weapon Challenge, ^{137}Cs RDD, Civilian Population, All Personnel Unprotected and without Medical Treatment

	Cutaneous Radiation				
CHALLENGE	CUT Rad: <200cGy	CUT Rad: 200-1500cGy	CUT Rad: 1500-4000cGy	CUT Rad: 4000-55000cGy	CUT Rad: >55000cGy
WB Rad: <125cGy	4,128,104	194,472	73,861	34,933	0
WB Rad: 125-300cGy	0	0	0	35,339	0
WB Rad: 300-450cGy	0	0	0	4,390	0
WB Rad: 450-830cGy	0	0	0	5,432	0
WB Rad: >830cGy	0	0	0	3,190	23,537

C. Effective Residual Radiation Challenge – Scenario 1-Fallout-0: Fallout from 10KT Ground Burst (IND), LIBN Scenario, All Personnel Unprotected

Residual radiation (primarily fallout) constitutes an operational concern over two distinct periods following a nuclear detonation: as the cloud of radioactive material passes over the military unit, and afterward when the contamination is present on the ground, vehicles, and structures. The first period includes the risk of inhalation of radioactive materials, as well as external irradiation from the cloud, and skin contamination as the radioactive material “falls out” to the ground. The second period generally does not pose an inhalation threat (assuming limited re-aerosolization from the contaminated ground, and/or adequate respiratory protection), but can pose an external irradiation threat and (with re-aerosolization) a skin contamination threat. The first period of concern is generally short (depending on weather conditions). The second period can last for weeks or months as the radioactive material decays away. For this study, the mission is to enter a fallout area approximately one day after the detonation (in the second time period of concern, when the contamination is present on the surface), and stay in the area for 24 hours.

The consideration of the fallout (residual radiation) resulting from the 10KT ground burst nuclear weapon in the vicinity of the LIBN could be regarded as a variation on the basic radiological scenario. In this illustration of a planning scenario, individuals remain in the fallout environment from 24 hours to 48 hours post-detonation. Radioactive material is no longer present in the air, but there is radioactive material on the ground.

The LIBN scenario is the same as discussed above, with 816 personnel distributed at 155 different locations in a roughly oval shaped area 2 km long and 1 km wide (with some personnel at locations as much as 200 m to either side). The original point of detonation of

the nuclear weapon (ground zero) is less than 200 m from the nearest unit personnel, and the prevailing wind is such that the fallout was carried over the unit area. Table 11 provides the effective residual radiation challenge estimated for the personnel in the LIBN. Just as for an RDD, the cells in this table are defined by the dose bands for whole body and cutaneous radiation, as described in AMedP-7.5 (see Appendix E). The upper left cell (WB Rad: <125cGy, CUT Rad: <200cGy) enumerates the personnel unaffected by the whole body and/or cutaneous radiation – in this case, 28, or only 3.4% of the unit.

Table 11. Effective Radiological Challenge, Fallout from 10KT Ground Burst (IND), LIBN Scenario, All Personnel Unprotected

	Cutaneous Radiation				
CHALLENGE	**CUT Rad: <200cGy**	**CUT Rad: 200-1500cGy**	**CUT Rad: 1500-4000cGy**	**CUT Rad: 4000-55000cGy**	**CUT Rad: >55000cGy**
WB Rad: <125cGy	28	226	0	0	0
WB Rad: 125-300cGy	0	108	337	0	0
WB Rad: 300-450cGy	0	0	74	0	0
WB Rad: 450-830cGy	0	0	0	36	0
WB Rad: >830cGy	0	0	0	7	0

4. Step 3: Estimate the Casualties

Within the NATO CBRN casualty estimation methodology, a CBRN casualty is defined as "any person who is lost to the organization by reason of having been declared dead, wounded, or diseased as a result of exposure to CBRN agents or effects."[11] The methodology examines three classes of casualty: individuals killed in action (KIA), individuals wounded in action (WIA), and individuals who DOW. A KIA is defined as "a battle casualty who is killed outright or who dies as a result of wounds or other injuries before reaching a medical treatment facility."[12] A WIA is defined as "a battle casualty who has incurred a non-fatal injury due to an external agent or cause as a result of hostile action."[13] Finally, a DOW is defined as "a battle casualty who died after having entered the medical care system." [14]

The NATO CBRN casualty estimation methodology directly associates cutaneous or whole-body radiation dose (or dose equivalent) (Gy or Sv) with injury severity. Similarly, the methodology associates primary static blast overpressure burden (kPa) and the percent of the body surface area (%BSA) with second degree (or greater) flash burns with injury severity. Burn surface area must be estimated based on the type of uniform assumed to be in use. The ranges of these effects and their associated severity are listed in Appendix E, which includes tables from AMedP-7.5 SD.3 current to the time of this analysis. In addition, for individuals in the open, the methodology estimates fatalities (KIA) arising from whole body translation — individuals being propelled through the air by the blast winds (dynamic pressure) — followed by tumbling along the open ground (decelerative tumbling). Time to death from whole body irradiation is estimated using a separate algorithm, as specified in AMedP-7.5.[15] This provides an estimate for when an individual would become DOW. Using this equation to estimate KIA (a dose that results in death in less than one hour) results in an estimated dose of greater than 1,200 Gy.

Within this analysis, it is assumed that anyone receiving any level of injury (severity level 1 (mild) or greater) will be a casualty. Based on the default value from AMedP-7.5 of 30 minutes as the time to reach a medical treatment facility (T_{MTF}),[16] personnel who die,

[11] AMedP-8(C), Glossary-1.

[12] North Atlantic Treaty Organization. *AAP-6: NATO glossary of terms and definitions (English and French)*. STANAG 3680. 2014, 2-K-1.

[13] North Atlantic Treaty Organization. *AAP-6: NATO glossary of terms and definitions (English and French)*. STANAG 3680. 2014 Mar, 2-W-2.

[14] North Atlantic Treaty Organization. *AAP-6: NATO glossary of terms and definitions (English and French)*. STANAG 3680. 2010 Mar, 2-D-6.

[15] AMedP-8(C), 4-7.

[16] AMedP-7.5, Study Draft 3, Table 2-14, 2-15.

or are at severity level 4 (very severe) for more than 15 minutes within 30 minutes of the start of exposure, will be regarded as KIA. Personnel who die after 30 minutes will be regarded as DOW.

Ultimately, all that is required by the NATO CBRN casualty estimation methodology for radiological or nuclear incidents is an estimate of how much radiation (whole body or cutaneous), static overpressure, and burn is experienced by each populated icon in the scenario. All of the discussion above provides the basis for that estimate. Appendix E includes tables excerpted from AMedP-7.5 that are pertinent to estimating casualties from prompt nuclear effects or radiological exposures, including the criteria used to categorize casualties. AMedP-7.5, as it is currently proposed, allows the estimation of casualties without consideration of protection, with consideration of protection, and/or with consideration of medical treatment. Medical treatment for nuclear and radiological tragedies can be with or without G-CSF. For each of these cases, there are at least two casualty estimate tables:

- Estimated of New Casualties, by Day (which can also be presented as Estimated Daily Number of New Casualties per 100 of the PAR); and,
- Estimated Cumulative Casualties, by Day.

A. Nuclear Weapons

The basic nuclear scenario, as presented in the AMedP-7.5 Illustrative Examples, is a 10KT ground burst (which can be regarded as an IND) in the vicinity of a military unit, in this case the LIBN. There are 816 personnel considered in the LIBN scenario, distributed at 155 different locations in a roughly oval shape 2 km long and 1 km wide (with some personnel at locations as far as 200 m to either side). The point of detonation of the nuclear weapon (ground zero) is less than 200 m from the nearest unit personnel. Alternative analyses to illustrate casualty estimation in the current analysis include a 10KT ground burst in the vicinity of a civilian population and a 10KT low air burst in the vicinity of the LIBN.

AMedP-7.5 provides the injury profiles (severity over time) for whole body radiation, blast static overpressure, and thermal fluence (see Appendix E). From these tables of injury severity, it is possible to estimate the severity of injuries for each individual in the unit. From AMedP-7.5, the rules for estimating the injury severity resulting from multiple prompt nuclear effects are relatively straightforward.[17] When not considering the impact of medical treatment:

[17] AMedP-7.5, SD.3, Working Copy, 26 October 2015, 6-5.

1. If any of the three effects result in KIA, the icon should be reported as KIA on day 1.
2. Any icon that is WIA but not KIA should be reported as WIA on day 1, with the maximum severity of all three injuries on day 1 included.
3. Casualty becomes DOW (moves from the WIA row to the DOW row) at the earliest time that any of the three injuries indicates.

1. Scenario 1-N-Grd-0: 10KT Ground Burst (IND), LIBN Scenario, Without Considering Protection or Medical Care

From the effective nuclear weapon challenge listed in Table 2, Table 12 provides an estimate of the new casualties occurring by day, and Table 13 provides an estimate of the casualty status of the unit personnel on each day. Note that these casualty estimates do not consider protection from prompt nuclear effects that would be provided by the vehicle, structures and emplacements that would be in use by the LIBN in this scenario. The protection afforded by the uniform is considered, though, to estimate the severity of burns resulting from exposure to the thermal fluence from the nuclear detonation.

From these tables, it is possible to estimate the operational impact of a 10KT ground burst on this unit in this scenario. Without protection, all personnel become casualties, 21 people are KIA and 795 are WIA on the first day. Rapidly, by the second day, a large number of personnel (357) succumb to their wounds and are reclassified as DOW. (Note that this estimate is made without consideration of the impact of providing medical care.) Over the ensuing 60 days, 212 more personnel will die from their wounds, and 203 personnel will recover and return to duty (RTD). From an operational perspective, Table 12 allows a planner to estimate the operational capability of the unit – in this case, the unit is clearly incapacitated.

Table 12. New Casualties Occurring (by Day) from Prompt Nuclear Effects, 10 KT Ground Burst, LIBN, All Personnel Unprotected and without Medical Treatment*

Casualty Description	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7	DAYS 8-14	DAYS 15-30	DAYS 31+
KIA (Nuclear)	21	0	0	0	0	0	0	0	0	0
DOW (Nuclear)	0	357	4	32	13	19	10	44	49	41
Sum of New Fatalities	21	357	4	32	13	19	10	44	49	41
New WIA	795	0	0	0	0	0	0	0	0	0
New RTD	0	0	0	0	0	0	0	0	203	0

* Estimate is based on Casualty Criterion WIA(1+) and a PAR of 816.

Table 13 provides an estimate of the cumulative casualty status of the unit personnel on each day. Table 13 also provides, in accordance with AMedP-7.5, a detailed categorization of the different types and severity of injuries associated with the WIA casualties. This detailed categorization may be of use to the medical planner in determining the amount of medical material and support that might be needed for different types of casualties. This also allows for an analysis of the ongoing health of the casualties. If the planner has algorithms or tools that allow the estimation of personnel replacement or medical care requirements, those requirements can be summed for the whole unit, over time, to allow for the most effective response to this nuclear scenario.

Table 13. Cumulative Casualties Occurring by Combination of Prompt Nuclear Effects, 10 KT Ground Burst, LIBN, All Personnel Unprotected and without Medical Treatment*

Casualty Description	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7	DAYS 8-14	DAYS 15-30	DAYS 31+
Fatalities										
KIA (Nuclear)	21	21	21	21	21	21	21	21	21	21
DOW (Nuclear)	0	357	361	393	406	425	435	479	528	569
Sum of Fatalities	21	378	382	414	427	446	456	500	549	590
WIA†										
R0, B0, T1	0	203	0	0	0	0	0	0	0	0
R1, B0, T1	0	23	0	0	0	0	0	0	0	0
R0, B0, T2	0	0	226	267	226	226	226	203	0	0
R1, B0, T2	0	0	41	0	41	41	41	0	0	0
R1, B2, T1	203	0	0	0	0	0	0	0	0	0
R2, B0, T0	0	0	0	0	0	0	0	0	23	0
R2, B0, T1	0	41	0	0	0	0	0	0	0	0
R2, B0, T2	0	0	0	0	0	0	0	64	0	0
R3, B0, T0	0	0	0	0	0	0	0	0	41	23
R3, B0, T1	0	19	0	0	0	0	0	0	0	0
R3, B0, T2	0	70	89	89	89	89	89	0	0	0
R3, B0, T3	0	82	78	46	33	14	4	0	0	0
R3, B2, T1	83	0	0	0	0	0	0	0	0	0
R3, B2, T2	70	0	0	0	0	0	0	0	0	0
R3, B2, T3	82	0	0	0	0	0	0	0	0	0
R3, B2, T4	279	0	0	0	0	0	0	0	0	0
R3, B3, T4	78	0	0	0	0	0	0	0	0	0
R4, B0, T2	0	0	0	0	0	0	0	49	0	0
Sum of WIA	795	438	434	402	389	370	360	316	64	23
RTD										

Casualty Description	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7	DAYS 8-14	DAYS 15-30	DAYS 31+
RTD	0	0	0	0	0	0	0	0	203	203

* Estimate is based on Casualty Criterion WIA(1+) and a PAR of 816.
† Any WIA row that has a population of zero is excluded from the table.
NOTE that rounding to nearest whole number may result in a “0” indication when a fractional casualty estimate less than 0.5 is made.

2. Scenario 1-N-Grd-P: 10KT Ground Burst (IND), LIBN Scenario, Considering Protection but not Medical Care

From the effective nuclear weapon challenge in Table 3, Table 14 provides an estimate of the new casualties occurring by day, and Table 15 provides an estimate of the cumulative casualty status of the unit personnel on each day. Considering protection changes the estimate of “New Casualties Occurring by Day” (Table 14) to reflect fewer WIA, DOW, and RTD. Without protection, all personnel become casualties, 21 people are KIA and 795 are WIA on the first day. With protection, 71 personnel are below the threshold for casualties in every effect (“Unaffected”), 725 become WIA and 21 become KIA. There are still a large number of personnel, 287, who rapidly succumb to their wounds and are reclassified as DOW by the second day. Over the ensuing 60 days, 275 more personnel will die from their wounds, and 140 personnel will recover and return to duty (RTD). Note that there are significantly fewer RTD; this is primarily due to the 71 personnel who did not become WIA. If the 71 unaffected personnel are summed with the 140 RTD, the total personnel who remain or return to duty goes from 203 (unprotected) to 211 (protected). From an operational perspective, Table 14 allows a planner to estimate the operational capability of the unit – in this case, even considering protection, 91% of the unit is WIA or KIA, and the unit is clearly incapacitated. From another perspective, the ability to model the efficacy of protection in improving the operational availability of the unit can assist the materiel development process in the definition of requirements for nuclear protection provided by uniforms, vehicles, and other military equipment.

Table 14. Casualties Occurring (by Day) from Prompt Nuclear Effects, 10 KT Ground Burst, LIBN, Protection Considered but without Medical Treatment*

Casualty Description	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7	DAYS 8-14	DAYS 15-30	DAYS 31+
KIA (Nuclear)	21	0	0	0	0	0	0	0	0	0
DOW (Nuclear)	0	287	40	15	17	12	2	66	75	49
Sum of New Fatalities	21	287	40	15	17	12	2	66	75	49
New WIA	725	0	0	0	0	0	0	0	0	0
New RTD	0	9	0	0	0	0	0	0	140	0

* Estimate is based on Casualty Criterion WIA(1+) and a PAR of 816.

Table 15. Cumulative Casualties Occurring by Combination of Prompt Nuclear Effects, 10 KT Ground Burst, LIBN, Protection Considered but without Medical Treatment*

Casualty Description	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7	DAYS 8-14	DAYS 15-30	DAYS 31+
Fatalities										
KIA (Nuclear)	21	21	21	21	21	21	21	21	21	21
DOW (Nuclear)	0	287	327	341	358	370	372	438	513	562
Sum of Fatalities	21	308	348	362	379	391	393	459	534	583
WIA†										
$R0_{4.5–8.3\ Gy}$, B0, T0§	0	0	7	13	7	7	7	0	0	0
R0, B0, T1	0	140	0	0	0	0	0	0	0	0
R1, B0, T0	0	7	7	0	7	7	7	0	0	0
R0, B0, T2	0	0	147	188	147	147	147	140	0	0
R1, B0, T2	0	0	41	0	41	41	41	0	0	0
R1, B2, T1	149	0	0	0	0	0	0	0	0	0
R2, B0, T0	0	7	0	0	0	0	0	13	14	0
R2, B0, T1	0	41	0	0	0	0	0	0	0	0
R2, B0, T2	0	0	0	0	0	0	0	48	0	0
R0, B0, T3	0	0	0	2	0	0	0	0	0	0
R1, B0, T3	0	0	2	0	2	2	2	0	0	0
R2, B0, T3	0	2	0	0	0	0	0	2	0	0
R3, B0, T0	0	113	81	74	65	54	53	0	48	14
R3, B0, T1	0	16	0	0	0	0	0	0	0	0
R3, B0, T2	0	57	73	73	73	73	73	0	0	0
R3, B0, T3	0	33	32	25	17	16	16	0	2	0
R3, B2, T0	0	8	0	0	0	0	0	0	0	0
R3, B2, T1	264	0	0	0	0	0	0	0	0	0
R3, B2, T2	57	0	0	0	0	0	0	0	0	0
R3, B2, T3	34	0	0	0	0	0	0	0	0	0
R3, B3, T1	51	0	0	0	0	0	0	0	0	0
R3, B2, T4	142	0	0	0	0	0	0	0	0	0
R3, B3, T4	27	0	0	0	0	0	0	0	0	0
R4, B0, T0	0	0	0	0	0	0	0	17	0	0
R4, B0, T2	0	0	0	0	0	0	0	58	0	0
R4, B0, T3	0	0	0	0	0	0	0	1	0	0
Sum of WIA	725	429	389	375	358	346	344	278	63	14
RTD										
RTD	0	9	9	9	9	9	9	9	149	149

* Estimate is based on Casualty Criterion WIA(1+) and a PAR of 816.

† Any WIA row that has a population of zero is excluded from the table.

§ This row is for untreated individuals in the 4.5 – 8.3 Gy whole-body radiation dose range who either sustained no thermal or blast injury, or have recovered from thermal or blast injuries; for the period between 72 and 96 hours, the radiation Injury Severity Level will be 0, but the Injury Severity Level will increase again at 96 hours, so the individuals cannot be RTD.

3. Scenario 1-N-Grd-M: 10KT Ground Burst (IND), LIBN Scenario, Considering Protection and Medical Care without Granulocyte-Colony Stimulating Factor (G-CSF)

From the AMedP-7.5 tables of medical outcomes, and the effective nuclear weapon challenge listed in Table 4, it is possible to estimate the outcome of injuries for each individual in the unit. Note that the consideration of medical care adds two new casualty categories to the casualty estimate: Convalescent (CONV), which includes patients who are "mostly ambulatory [and] require limited therapeutic intervention and administration of oral medications performed by the patient,"[18] or (alternatively) patients who are evacuated out of theatre for long-term recovery; and Return to Duty (RTD), which is "The administrative process of releasing a patient from medical treatment facility to his or her unit."[19] Thus, a CONV was previously WIA, but currently requires either no or minimal in-theatre medical resources, and an RTD was previously WIA (and possibly CONV), but has recovered without leaving the theatre.[20]

This also adds a new rule for estimating the outcome from AMedP-7.5: When considering the impact of medical treatment, and a casualty becomes CONV, then the casualty "moves from a WIA row to a CONV row. This occurs at the *latest* time that any of the three flowcharts indicates."[21] Considering medical treatment also shifts personnel who (without consideration of medical treatment) would be classified as RTD to instead be classified as CONV.

Table 16 provides an estimate of the new casualties occurring by day, and Table 17 provides an estimate of the cumulative casualty status of the unit personnel on each day. Medical care has no influence on the actual exposure an individual receives, but it does have a considerable influence on the casualty estimate for nuclear or radiological casualties: By the last time period considered (Days 31+), there are 42 fewer DOW, 14 fewer WIA, and 55 fewer RTD. All of these (111) personnel have been moved into the CONV category. Table 16 allows a planner to estimate the operational capability of the unit – in this case, medical care does not improve the operational capability of the unit until

[18] NATO, *AMedP-13(A)*, 2-15.

[19] NTMS, NATO Agreed 2014-06-25.

[20] NATO, AMedP-7.5, 1-11.

[21] AMedP-7.5, SD.3, Working Copy, 26 October 2015, 6-6.

the period Days 15-30, when 94 personnel (11.4%) are RTD. With only 71 personnel (8.7%) unaffected, the unit is clearly incapacitated.

Table 16. New Casualties Occurring (by Day) from Prompt Nuclear Effects, 10 KT Ground Burst, LIBN, Protection Considered and with Medical Treatment (w/o G-CSF)*

Casualty Description	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7	DAYS 8-14	DAYS 15-30	DAYS 31+
KIA (Nuclear)	21	0	0	0	0	0	0	0	0	0
DOW (Nuclear)	0	266	47	27	17	12	2	67	75	7
Sum of New Fatalities	21	266	47	27	17	12	2	67	75	7
New WIA	725	0	0	0	0	0	0	0	0	0
New CONV (Nuclear)	0	9	0	0	0	0	0	0	47	56
New RTD	0	0	0	0	0	0	0	0	94	0

* Estimate is based on Casualty Criterion WIA(1+) and a PAR of 816.

Table 17 allows for an analysis of the ongoing health of the casualties. If the planner has algorithms or tools that allow the estimation of personnel replacement or medical care requirements, those requirements can be summed for the whole unit, over time, to allow for the most effective response to this nuclear scenario. The CONV category also allows for the consideration of Role 4 or 5 medical care requirements.

Table 17. Cumulative Casualties Occurring by Combination of Prompt Nuclear Effects, 10 KT Ground Burst, LIBN, Protection Considered and with Medical Treatment (w/o G-CSF)*

Casualty Description	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7	DAYS 8-14	DAYS 15-30	DAYS 31+
Fatalities										
KIA (Nuclear)	21	21	21	21	21	21	21	21	21	21
DOW (Nuclear)	0	266	313	340	357	369	371	438	513	520
Sum of Fatalities	21	287	334	361	378	390	392	459	534	541
WIA†										
R0, B0, T1	0	140	140	140	140	140	140	140	0	0
R1, B2, T1	149	0	0	0	0	0	0	0	0	0
R2, B0, T0	0	0	0	0	0	0	0	0	14	0
R2, B0, T1	0	14	14	14	14	14	14	14	0	0
R2, B2, T1	14	0	0	0	0	0	0	0	0	0
R3, B0, T0	0	0	0	0	0	0	0	0	48	0
R3, B0, T1	0	176	145	137	128	118	116	80	0	0
R3, B0, T2	0	57	57	57	57	57	57	42	0	0
R3, B0, T3	0	55	47	28	20	18	18	2	2	0
R3, B2, T1	251	8	0	0	0	0	0	0	0	0
R3, B2, T2	57	0	0	0	0	0	0	0	0	0
R3, B2, T3	176	0	0	0	0	0	0	0	0	0
R3, B3, T1	51	0	0	0	0	0	0	0	0	0
R3, B3, T3	27	0	0	0	0	0	0	0	0	0
Sum of WIA	725	450	403	376	359	347	345	278	63	0
CONV†										
CONV (R)	0	9	9	9	9	9	9	9	55	110
CONV (B)	0	0	0	0	0	0	0	0	0	0
CONV (T)	0	0	0	0	0	0	0	0	0	0
CONV (R, B)	0	0	0	0	0	0	0	0	0	0
CONV (R, T)	0	0	0	0	0	0	0	0	0	1
CONV (B, T)	0	0	0	0	0	0	0	0	0	0
CONV (R, B, T)	0	0	0	0	0	0	0	0	0	0
Sum of CONV	0	9	9	9	9	9	9	9	55	111
RTD										
RTD	0	0	0	0	0	0	0	0	94	94

* Estimate is based on Casualty Criterion WIA(1+) and a PAR of 816.
† Any WIA row that has a population of zero is excluded from the table.
NOTE that rounding to nearest whole number may result in a “0” indication when a fractional casualty estimate less than 0.5 is made.

4. Scenario 1-N-Grd-G: 10KT Ground Burst (IND), LIBN Scenario, Considering Protection and Medical Care with G-CSF

The additional consideration of G-CSF changes the dose range for DOW, allowing personnel who have received up to 8.5Gy of whole body radiation to become CONV instead of DOW (without medical treatment, DOW is at doses greater than 4.5Gy; with medical treatment but without G-CSF, DOW is at doses greater than 6.3Gy).

Table 18 provides an estimate of the new casualties occurring by day, and Table 19 provides an estimate of the cumulative casualty status of the unit personnel on each day. For this scenario, medical care with G-CSF moves seven personnel from DOW to CONV. From an operational perspective, this does not change the operational capability of the unit (incapacitated), but does allow a slightly revised estimate of the medical care requirements, particularly for Role 4 or 5.

Table 18. New Casualties Occurring (by Day) from Prompt Nuclear Effects, 10 KT Ground Burst, LIBN, Protection Considered and with Medical Treatment (including G-CSF)*

Casualty Description	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7	DAYS 8-14	DAYS 15-30	DAYS 31+
KIA (Nuclear)	21	0	0	0	0	0	0	0	0	0
DOW (Nuclear)	0	266	47	27	17	12	2	67	75	0
Sum of New Fatalities	21	266	47	27	17	12	2	67	75	0
New WIA	725	0	0	0	0	0	0	0	0	0
New CONV (Nuclear)	0	9	0	0	0	0	0	0	47	63
New RTD	0	0	0	0	0	0	0	0	94	0

* Estimate is based on Casualty Criterion WIA(1+) and a PAR of 816.

Table 19. Cumulative Casualties Occurring by Combination of Prompt Nuclear Effects, 10 KT Ground Burst, LIBN, Protection Considered and with Medical Treatment (including G-CSF)*

Casualty Description	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7	DAYS 8-14	DAYS 15-30	DAYS 31+
Fatalities										
KIA (Nuclear)	21	21	21	21	21	21	21	21	21	21
DOW (Nuclear)	0	266	313	340	357	369	371	438	513	513
Sum of Fatalities	21	287	334	361	378	390	392	459	534	534
WIA†										
R0, B0, T1	0	140	140	140	140	140	140	140	0	0
R1, B2, T1	149	0	0	0	0	0	0	0	0	0
R2, B0, T0	0	0	0	0	0	0	0	0	14	0
R2, B0, T1	0	14	14	14	14	14	14	14	0	0
R2, B2, T1	14	0	0	0	0	0	0	0	0	0
R3, B0, T0	0	0	0	0	0	0	0	0	48	0
R3, B0, T1	0	176	145	137	128	118	116	80	0	0
R3, B0, T2	0	57	57	57	57	57	57	42	0	0
R3, B0, T3	0	55	47	28	20	18	18	2	2	0
R3, B2, T1	251	8	0	0	0	0	0	0	0	0
R3, B2, T2	57	0	0	0	0	0	0	0	0	0
R3, B2, T3	176	0	0	0	0	0	0	0	0	0
R3, B3, T1	51	0	0	0	0	0	0	0	0	0
R3, B3, T3	27	0	0	0	0	0	0	0	0	0
Sum of WIA	725	450	403	376	359	347	345	278	63	0
CONV†										
CONV (R)	0	9	9	9	9	9	9	9	55	117
CONV (B)	0	0	0	0	0	0	0	0	0	0
CONV (T)	0	0	0	0	0	0	0	0	0	0
CONV (R, B)	0	0	0	0	0	0	0	0	0	0
CONV (R, T)	0	0	0	0	0	0	0	0	0	1
CONV (B, T)	0	0	0	0	0	0	0	0	0	0
CONV (R, B, T)	0	0	0	0	0	0	0	0	0	0
Sum of CONV	0	9	9	9	9	9	9	9	55	118
RTD										
RTD	0	0	0	0	0	0	0	0	94	94

* Estimate is based on Casualty Criterion WIA(1+) and a PAR of 816.
† Any WIA row that has a population of zero is excluded from the table.
NOTE that rounding to nearest whole number may result in a "0" indication when a fractional casualty estimate less than 0.5 is made.

5. Scenario 2-N-Grd-0: 10KT Ground Burst (IND), Civilian Population Scenario, Without Considering Protection or Medical Care

From the effective nuclear weapon challenge listed in Table 5, Table 20 provides an estimate of the new casualties occurring by day, and Table 21 provides an estimate of the cumulative casualty status of the unit personnel on each day. Note that these casualty estimates do not consider protection from prompt nuclear effects that would be provided by vehicle or structures that would be in use by the civilian personnel in this scenario. The protection afforded by clothing is considered, though, to estimate the severity of burns resulting from exposure to the thermal fluence from the nuclear detonation. Clothing is assumed to provide protection equivalent to that of a military uniform. Because protection is not considered, the estimates in Table 5, Table 20, and Table 21 are likely overestimates, providing upper bounds on the severity of injuries and the number of casualties.

Table 20. Casualties Occurring (by Day) from Prompt Nuclear Effects, 10 KT Ground Burst, Civilian Population, All Personnel Unprotected and without Medical Treatment*

Casualty Description	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7	DAYS 8-14	DAYS 15-30	DAYS 31+
KIA	48,623	0	0	0	0	0	0	0	0	0
DOW	0	208,363	457	13,780	8,709	11,210	5,523	30,410	23,495	33,570
Sum of New	48,623	208,363	457	13,780	8,709	11,210	5,523	30,410	23,495	33,570
New WIA	581,889	0	0	0	0	0	0	0	0	0
New RTD	0	0	0	0	0	0	0	0	228,977	0

* Estimate is based on Casualty Criterion WIA(1+) and a PAR of 1,116,207.

Table 21. Cumulative Casualties Occurring by Combination of Prompt Nuclear Effects, 10 KT Ground Burst, Civilian Population, All Personnel Unprotected and without Medical Treatment*

Casualty Description	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7	DAYS 8-14	DAYS 15-30	DAYS 31+
Fatalities										
KIA (Nuclear)	48,623	48,623	48,623	48,623	48,623	48,623	48,623	48,623	48,623	48,623
DOW (Nuclear)	0	208,363	208,820	222,600	231,309	242,519	248,041	278,452	301,947	335,517
Sum of Fatalities	48,623	256,986	257,443	271,223	279,932	291,141	296,664	327,074	350,569	384,140
WIA†										
R0, B0, T1	0	228,977	0	0	0	0	0	0	0	0
R1, B0, T1	0	17,395	0	0	0	0	0	0	0	0
R0, B0, T2	0	0	246,372	280,453	246,372	246,372	246,372	228,977	0	0
R1, B0, T2	0	0	34,080	0	34,080	34,080	34,080	0	0	0
R1, B2, T1	228,977	0	0	0	0	0	0	0	0	0

Casualty Description	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7	DAYS 8-14	DAYS 15-30	DAYS 31+
R2, B0, T0	0	0	0	0	0	0	0	0	17,395	0
R2, B0, T1	0	34,080	0	0	0	0	0	0	0	0
R2, B0, T2	0	0	0	0	0	0	0	51,475	0	0
R3, B0, T0	0	0	0	0	0	0	0	0	33,570	17,395
R3, B0, T1	0	9,776	0	0	0	0	0	0	0	0
R3, B0, T2	0	30,813	40,589	40,589	40,589	40,589	40,589	0	0	0
R3, B0, T3	0	52,484	52,027	38,247	29,538	18,329	12,806	0	0	0
R3, B2, T1	61,251	0	0	0	0	0	0	0	0	0
R3, B2, T2	30,813	0	0	0	0	0	0	0	0	0
R3, B2, T3	52,484	0	0	0	0	0	0	0	0	0
R3, B2, T4	164,694	0	0	0	0	0	0	0	0	0
R3, B3, T4	43,669	0	0	0	0	0	0	0	0	0
R4, B0, T2	0	0	0	0	0	0	0	22,985	0	0
Sum of WIA	581,889	373,526	373,069	359,289	350,580	339,371	333,848	303,438	50,966	17,395
RTD										
RTD	0	0	0	0	0	0	0	0	228,977	228,977

* Estimate is based on Casualty Criterion WIA(1+) and a PAR of 1,116,207.

† Any WIA row that has a population of zero is excluded from the table.

NOTE that rounding to nearest whole number may result in a “0” indication when a fractional casualty estimate less than 0.5 is made.

The “casualty status” of the unit personnel in Table 21 allows for an analysis of the ongoing health of the casualties, and some characterization of the medical response that would be required. As noted above, 485,695 people, or about 44% of the considered population, are unaffected by significant levels of the prompt effects. However, 48,623 are expected to be prompt fatalities, and 581,889 have injuries that are not immediately lethal. Of the injured, 335,517 people are estimated to succumb to their injuries over the next 60 days and 246,372 are expected to recover, eventually. This scenario poses a huge challenge for the planner attempting to provide evacuation, triage, and care for hundreds of thousands of casualties.

6. Scenario 1-N-Air-0: 10KT Low Air Burst (HoB = 129m), LIBN Scenario, Without Considering Protection or Medical Care

Table 22 provides an estimate of the new casualties occurring by day, and Table 23 provides an estimate of the cumulative casualty status of the unit personnel on each day. Without protection from prompt nuclear effects that would be provided by the vehicles, structures, and emplacements that would be in use by the LIBN in this scenario, all personnel are casualties, and all die within the first two days post exposure. The operational

impact is as severe as it can be, and the considerations of personnel replacement and the health status of the unit are moot.

Table 22. New Casualties Occurring (by Day) from Prompt Nuclear Effects, 10 KT Low Air Burst (HoB = 129m), LIBN, All Personnel Unprotected and without Medical Treatment*

Casualty Description	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7	DAYS 8-14	DAYS 15-30	DAYS 31+
KIA (Nuclear)	14	0	0	0	0	0	0	0	0	0
DOW (Nuclear)	0	802	0	0	0	0	0	0	0	0
Sum of New Fatalities	14	802	0	0	0	0	0	0	0	0
New WIA	802	0	0	0	0	0	0	0	0	0
New RTD	0	0	0	0	0	0	0	0	0	0

* Estimate is based on Casualty Criterion WIA(1+) and a PAR of 816.

Table 23. Cumulative Casualties Occurring by Combination of Prompt Nuclear Effects, 10 KT Low Air Burst (HoB = 129m), LIBN, All Personnel Unprotected and without Medical Treatment*

Casualty Description	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7	DAYS 8-14	DAYS 15-30	DAYS 31+
Fatalities										
KIA (Nuclear)	14	14	14	14	14	14	14	14	14	14
DOW (Nuclear)	0	802	802	802	802	802	802	802	802	802
Sum of Fatalities	14	816	816	816	816	816	816	816	816	816
WIA†										
R1, B2, T4	168	0	0	0	0	0	0	0	0	0
R3, B2, T4	547	0	0	0	0	0	0	0	0	0
R3, B3, T4	87	0	0	0	0	0	0	0	0	0
Sum of WIA	802	0	0	0	0	0	0	0	0	0
RTD										
RTD	0	0	0	0	0	0	0	0	0	0

* Estimate is based on Casualty Criterion WIA(1+) and a PAR of 816.
† Any WIA row that has a population of zero is excluded from the table.
NOTE that rounding to nearest whole number may result in a “0” indication when a fractional casualty estimate less than 0.5 is made.

7. Scenario 1-N-Air-G: 10KT Low Air Burst (HoB = 129m), LIBN Scenario, Considering Protection and Medical Care with G-CSF

Table 24 provides an estimate of the new casualties occurring by day, and Table 25 provides an estimate of the cumulative casualty status of the unit personnel on each day. From these tables, 54 personnel are unaffected, 14 are KIA, and 748 are WIA. By the end

of the period considered, of the 748 WIA, 670 are DOW and 78 are CONV. In this scenario, a low air burst (129m HoB) 10KT nuclear weapon, even with consideration of protection and medical treatment, will still produce a casualty rate of more than 93%, and totally incapacitate the unit.

Table 24. New Casualties Occurring (by Day) from Prompt Nuclear Effects, 10 KT Low Air Burst (HoB = 129m), LIBN, Protection Considered and with Medical Treatment (including G-CSF)*

Casualty Description	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7	DAYS 8-14	DAYS 15-30	DAYS 31+
KIA (Nuclear)	14	0	0	0	0	0	0	0	0	0
DOW (Nuclear)	0	293	58	25	14	11	217	33	19	0
Sum of New Fatalities	14	293	58	25	14	11	217	33	19	0
New WIA	748	0	0	0	0	0	0	0	0	0
New CONV (Nuclear)	0	24	0	0	0	0	0	0	0	54
New RTD	0	0	0	0	0	0	0	0	0	0

* Estimate is based on Casualty Criterion WIA(1+) and a PAR of 816

Table 25. Cumulative Casualties Occurring by Combination of Prompt Nuclear Effects, 10 KT Low Air Burst (HoB = 129m), LIBN, Protection Considered and with Medical Treatment (including G-CSF)*

Casualty Description	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7	DAYS 8-14	DAYS 15-30	DAYS 31+
Fatalities										
KIA (Nuclear)	14	14	14	14	14	14	14	14	14	14
DOW (Nuclear)	0	293	351	376	390	401	618	651	670	670
Sum of Fatalities	14	307	365	390	404	415	632	665	684	684
WIA†										
R1, B2, T1	24	0	0	0	0	0	0	0	0	0
R2, B0, T0	0	0	0	0	0	0	0	0	1	0
R2, B0, T1	0	1	1	1	1	1	1	1	0	0
R2, B2, T1	1	0	0	0	0	0	0	0	0	0
R0, B0, T3	0	108	108	108	108	108	27	27	27	0
R1, B2, T3	108	0	0	0	0	0	0	0	0	0
R2, B0, T3	0	32	32	32	32	32	8	8	8	0
R2, B2, T3	32	0	0	0	0	0	0	0	0	0
R3, B0, T0	0	0	0	0	0	0	0	0	10	0
R3, B0, T1	0	104	87	67	64	57	41	21	0	0
R3, B0, T3	0	172	145	140	129	125	29	17	8	0

Casualty Description	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7	DAYS 8-14	DAYS 15-30	DAYS 31+
R3, B2, T1	200	13	0	0	0	0	0	0	0	0
R3, B2, T3	296	1	0	0	0	0	0	0	0	0
R3, B3, T1	51	0	0	0	0	0	0	0	0	0
R3, B3, T3	36	0	0	0	0	0	0	0	0	0
Sum of WIA	748	431	373	348	334	323	106	73	54	0
CONV†										
CONV (R)	0	24	24	24	24	24	24	24	24	35
CONV (B)	0	0	0	0	0	0	0	0	0	0
CONV (T)	0	0	0	0	0	0	0	0	0	15
CONV (R, B)	0	0	0	0	0	0	0	0	0	0
CONV (R, T)	0	0	0	0	0	0	0	0	0	29
CONV (B, T)	0	0	0	0	0	0	0	0	0	0
CONV (R, B, T)	0	0	0	0	0	0	0	0	0	0
Sum of CONV	0	24	24	24	24	24	24	24	24	78
RTD										
RTD	0	0	0	0	0	0	0	0	0	0

* Estimate is based on Casualty Criterion WIA(1+) and a PAR of 816.
† Any WIA row that has a population of zero is excluded from the table.
NOTE that rounding to nearest whole number may result in a "0" indication when a fractional casualty estimate less than 0.5 is made.

B. Radiological Weapons

The basic radiological challenge, as presented in the AMedP-7.5 Illustrative Examples,[22] is an attack from an improvised radiological device comprised of a truck-borne high explosive intermingled with $1.11x10^5$ terabecquerels (34.5 kg) of the radioisotope Cesium-137 (^{137}Cs) in the vicinity of the LIBN. (This is equivalent to the radioactivity present in a large food irradiator facility.) To illustrate alternative casualty estimates, the current analysis includes a 740 TBq (147 g) ^{90}Sr source, a 0.37 TBq (3 g) ^{241}Am source, a 10 TBq (16 g) ^{238}Pu source (all of these are typical of large commercial sources), and the fallout (residual radiation) resulting from the 10KT ground burst nuclear weapon in the vicinity of the LIBN. The different isotopes and amounts allow for consideration of radiological weapon effects with different radiations and activities.

Note that the dose for whole body radiation from radioactive material in the air ("cloudshine"), radioactive material on the ground ("groundshine"), or cutaneous radiation

[22] AMedP-7.5, SD.3, Working Copy, 26 October 2015, A-31.

dose is estimated from the time integrated concentration of radioactive material in the air or ground, using the conversion factors provided in AMedP-7.5 (see Appendix E).[23]

For illustrative purposes, the RDD example assumes 1,000 kg of high explosive are used for dispersal of the radioactive material from the same location as the nuclear weapon example. To estimate the total exposure time, individuals are assumed to remain in the environment for a total of four hours after the RDD detonates, or in the fallout environment for 24 hours (beginning one day after the detonation).

1. Scenario 1-CsRDD-0: ^{137}Cs RDD, LIBN Scenario, Without Considering Protection or Medical Care

AMedP-7.5 (see Appendix E) provides the injury profiles (severity over time) for cutaneous and whole body radiation, respectively. From these tables of injury severity, and the effective radiological weapon challenge listed in Table 9, it is possible to estimate the severity of injuries for each individual in the unit.

From this effective radiological weapon challenge, Table 26 provides an estimate of the new casualties occurring by day, and Table 27 provides an estimate of the cumulative casualty status of the unit personnel on each day. Note that these casualty estimates do not consider protection from radiation that would be provided by the vehicles, structures, and emplacements that would be in use by the LIBN in this scenario.

Table 26. New Casualties Occurring (by Day) from ^{137}Cs RDD, LIBN, All Personnel Unprotected and without Medical Treatment*

Casualty Description	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7	DAYS 8-14	DAYS 15-30	DAYS 31+
KIA	0	0	0	0	0	0	0	0	0	0
DOW	0	0	0	0	0	0	0	0	0	0
Sum of New Fatalities	0	0	0	0	0	0	0	0	0	0
New WIA (Radiological)	251	0	0	0	0	0	0	0	0	0
New RTD	0	0	244	0	0	0	0	0	0	0

* Estimate is based on Casualty Criterion WIA(1+) and a PAR of 816.

23 AMedP-7.5, SD.3, Working Copy, 26 October 2015, 3-3.

Table 27. Cumulative Casualties Occurring from ^{137}Cs RDD, LIBN, All Personnel Unprotected and without Medical Treatment*

Casualty Description	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7	DAYS 8-14	DAYS 15-30	DAYS 31+
Fatalities										
KIA (Radiological)	0	0	0	0	0	0	0	0	0	0
DOW (Radiological)	0	0	0	0	0	0	0	0	0	0
Sum of Fatalities	0	0	0	0	0	0	0	0	0	0
WIA†										
R-0, C-1	244	251	0	0	0	0	0	0	0	0
R-0, C-2	0	0	7	7	7	7	7	0	0	0
R-0, C-3	0	0	0	0	0	0	0	7	7	7
R-1, C-1	7	0	0	0	0	0	0	0	0	0
Sum of WIA	251	251	7	7	7	7	7	7	7	7
RTD										
RTD	0	0	244	244	244	244	244	244	244	244

* Estimate is based on Casualty Criterion WIA(1+) and a PAR of 816.

† Any WIA row that has a population of zero is excluded from the table.

NOTE that rounding to nearest whole number may result in a “0” indication when a fractional casualty estimate less than 0.5 is made.

From these tables, it is possible to estimate the operational impact of a ^{137}Cs RDD on this unit in this scenario. Without protection, 251 personnel become casualties (about 31%) and none are KIA. Rapidly; by the third day, a large number of personnel (244) recover from their wounds and are reclassified as RTD. (Note that this estimate is made without consideration of the impact of providing medical care.) From an operational perspective, Table 26 allows a planner to estimate the operational capability of the unit – in this case, the unit is incapacitated from the radiation exposure.

The casualty status of the unit personnel in Table 27 allows for an analysis of the projected health of the casualties over time. If the planner has algorithms or tools that allow the estimation or personnel replacement or medical care requirements, those requirements can be summed for the whole unit, over time, to allow for the most effective response to this radiological scenario.

2. Scenario 1-SrRDD-0: ^{90}Sr RDD, LIBN Scenario, Without Considering Protection or Medical Care

An excursion (variation) on the baseline explosive RDD scenario is the use of ^{90}Sr as the radioisotope of interest. ^{137}Cs is used in the baseline because it is used in a wide variety of commercial practices and is typically in a form readily applicable to the variety of types of RDD. ^{90}Sr is used for the first RDD excursion because, although not as common as

^{137}Cs, ^{90}Sr also has a significant variety of commercial practices, some of which have large amounts of radioactive material. In this excursion, the ^{90}Sr source has an activity of 740 TBq (corresponding to a radioisotopic thermoelectric generator (RTG) with 147 g of ^{90}Sr). All other conditions in the RDD scenario are the same. Another reason for selecting ^{90}Sr as an excursion on the ^{137}Cs baseline scenario is that ^{90}Sr emits a beta particle with no gamma radiation as it decays to yttrium-90 (also a beta-emitter). ^{90}Sr has a half-life of 29.1 years. It behaves chemically much like calcium, and therefore tends to concentrate in the bones and teeth.[24] This excursion produced no casualties in the estimate, with no significant whole body radiation (maximum of 5.38×10^{-3} cGy) and a maximum of 75.6 cGy of cutaneous radiation.

3. Scenario 1-AmRDD-0: ^{241}Am RDD

A second excursion on the baseline explosive RDD scenario is the use of ^{241}Am as the radioisotope of interest. ^{241}Am is used for the second RDD excursion because ^{241}Am is present in most household and industrial smoke detectors, although in very small amounts (3.7×10^{-8} TBq, 1 μCi). In this excursion, the ^{241}Am source has an activity of 0.37 TBq (corresponding to the typical activity found in a calibration facility, and 3 g of ^{241}Am). All other conditions in the RDD scenario are the same. Another reason for the selection of ^{241}Am as an excursion on the ^{137}Cs baseline scenario is that ^{241}Am primarily emits alpha particles, but also emits gamma rays. A mixture of ^{241}Am and beryllium emits neutrons. ^{241}Am has a half-life of 432.7 years. Once in the body, ^{241}Am tends to concentrate in the bone, liver, and muscle. It stays in the body for decades and continues to expose the surrounding tissues to radiation.[25] This excursion produced no casualties in the estimate, with no significant whole body radiation or cutaneous radiation (maximums of 1.82×10^{-5} and 1.92×10^{-4} cGy, respectively).

4. Scenario 1-PuRDD-0: ^{238}Pu RDD

A third excursion (variation) on the baseline explosive RDD scenario is the use of ^{238}Pu as the radioisotope of interest. ^{238}Pu is used for the third RDD excursion because, although ^{238}Pu is present in only a limited number of commercial practices, the element plutonium is commonly associated with military threats, in particular a nuclear weapon. (^{239}Pu is used in nuclear weapons.) In this excursion, the ^{238}Pu source has an activity of 10 TBq (corresponding to the typical activity found in an RTG, with 16 g of ^{238}Pu). All other conditions in the RDD scenario are the same. Another reason for the selection of ^{238}Pu as an excursion on the ^{137}Cs baseline scenario is that ^{238}Pu emits alpha particles, with little

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[24] USEPA, Radiation Protection Reference Information on Strontium, http://www.epa.gov/radiation/radionuclides/strontium.html, accessed 3 August 2015.

[25] USEPA, Radiation Protection Reference Information on Americium, http://www.epa.gov/radiation/radionuclides/americium.html, accessed 3 August 2015.

emission of other types of radiation. (A mixture of ^{239}Pu and beryllium emits neutrons.) ^{238}Pu has a half-life of 87.7 years. Once inhaled, insoluble ^{238}Pu stays in the lungs until removed by mucocilliary activity and excreted. If soluble, ^{238}Pu can enter the bloodstream and from there it can get into bone, liver, and other body organs. It can stay in the body for decades and continue to expose the surrounding tissues to radiation.[26] This excursion produced no casualties in the estimate, with no significant whole body radiation or cutaneous radiation (maximums of 2.69×10^{-4} and 1.24×10^{-3} cGy, respectively).

5. Scenario 2-CsRDD-0: ^{137}Cs RDD, Civilian Population Scenario, Without Considering Protection or Medical Care

From the effective radiological weapon challenge levels in Table 10, Table 28 provides an estimate of the new casualties occurring by day, and Table 29 provides an estimate of the cumulative casualty status of the affected personnel on each day. Note that these casualty estimates do not consider protection from radiation or radioactive material that would be provided by vehicles or structures that would be in use by the civilian personnel in this scenario. Because protection is not considered, the estimates in Table 10, Table 28, and Table 29 are likely overestimates, providing upper bounds on the severity of injuries and the number of casualties.

Table 28. New Casualties Occurring (by Day) from ^{137}Cs RDD, Civilian Population Scenario, All Personnel Unprotected and without Medical Treatment*

Casualty Description	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7	DAYS 8-14	DAYS 15-30	DAYS 31+
KIA	0	0	0	0	0	0	0	0	0	0
DOW (Radiological)	0	4,823	1,783	1,532	1,532	1,382	1,633	8,666	5,752	5,055
Sum of New Fatalities	0	4,823	1,783	1,532	1.532	1,382	1,633	8,666	5,752	5,055
New WIA (Radiological)	375,154	0	0	0	0	0	0	0	0	0
New RTD	0	0	268,333	0	0	0	0	0	0	0

* Estimate is based on Casualty Criterion WIA(1+) and a PAR of 4,503,258.

[26] USEPA, Radiation Protection Reference Information on Plutonium, http://www.epa.gov/radiation/radionuclides/plutonium.html, accessed 3 August 2015.

Table 29. Cumulative Casualties Occurring from ^{137}Cs RDD, Civilian Population Scenario, All Personnel Unprotected and without Medical Treatment*

Casualty Description	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7	DAYS 8-14	DAYS 15-30	DAYS 31+
Fatalities										
KIA (Radiological)	0	0	0	0	0	0	0	0	0	0
DOW (Radiological)	0	4,823	6,606	8,139	9,671	11,052	12,685	21,351	27,104	32,159
Sum of Fatalities	0	4,823	6,606	8,139	9,671	11,052	12,685	21,351	27,104	32,159
WIA†										
R-0, C-1	303,266	338,605	0	0	0	0	0	0	0	0
R-0, C-2	0	0	74,662	80,094	74,662	74,662	74,662	0	0	0
R-0, C-3	0	0	0	0	0	0	0	70,272	70,272	70,272
R-1, C-1	35,339	4,390	0	0	0	0	0	0	0	0
R-1, C-2	0	0	5,432	0	5,432	5,432	5,432	0	0	0
R-2, C-1	0	5,432	0	0	0	0	0	0	0	0
R-2, C-3	0	0	0	0	0	0	0	9,822	4,390	0
R-3, C-1	36,549	3,190	0	0	0	0	0	0	0	0
R-3, C-2	0	18,714	20,121	18,588	17,056	15,674	14,042	0	0	0
R-3, C-3	0	0	0	0	0	0	0	0	5,055	4,390
R-4, C-3	0	0	0	0	0	0	0	5,376	0	0
Sum of WIA	375,154	370,331	100,214	98,682	97,150	95,768	94,135	85,469	79,717	74,662
RTD										
RTD	0	0	268,333	268,333	268,333	268,333	268,333	268,333	268,333	268,333

* Estimate is based on Casualty Criterion WIA(1+) and a PAR of 4,503,258.

† Any WIA row that has a population of zero is excluded from the table.

NOTE that rounding to nearest whole number may result in a “0” indication when a fractional casualty estimate less than 0.5 is made.

For comparison, the civilian population scenario was also run with ^{90}Sr, ^{238}Pu, and ^{241}Am RDDs. Compared to the ^{137}Cs RDD, which resulted in 375,154 casualties, the ^{90}Sr RDD resulted in a considerably less, although still significant, 33,622 casualties, and the ^{238}Pu and ^{241}Am RDDs resulted in no (0) casualties.

6. Scenario 1-Fallout-0: Fallout from 10KT Ground Burst (IND), LIBN Scenario, Without Considering Protection or Medical Care

AMedP-7.5 (see Appendix E) provides the injury profiles (severity over time) for cutaneous and whole body radiation, respectively. From these tables of injury severity, and the effective residual radiation challenge listed in Table 11, it is possible to estimate the severity of injuries for each individual in the unit. Table 30 provides an estimate of the new casualties occurring by day, and Table 31 provides an estimate of the cumulative casualty status of the unit personnel on each day. Note that these casualty estimates do not consider protection from radiation that would be provided by the vehicles, structures, and emplacements that would be in use by the LIBN in this scenario.

From these tables, it is possible to estimate the operational impact of fallout on this unit in this scenario. Without protection, 788 personnel become casualties (about 97%) and no personnel are KIA. Rapidly, by the third day, a large number of personnel (244) recover from their wounds and are reclassified as RTD, although 43 personnel are expected to eventually die from their dose. (Note that this estimate is made without consideration of the impact of providing medical care.) From an operational perspective, Table 31 allows a planner to estimate the operational capability of the unit – in this case, the unit is incapacitated from the radiation exposure.

Table 30. New Casualties Occurring (by Day) from Fallout from 10KT Ground Burst (IND), LIBN Scenario, All Personnel Unprotected and without Medical Treatment*

Casualty Description	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7	DAYS 8-14	DAYS 15-30	DAYS 31+
KIA (Radiological)	0	0	0	0	0	0	0	0	0	0
DOW (Radiological)	0	0	0	0	0	0	0	0	7	36
Sum of New Fatalities	0	0	0	0	0	0	0	0	7	36
New WIA (Radiological)	788	0	0	0	0	0	0	0	0	0
New RTD	0	0	671	0	0	0	0	0	0	0

* Estimate is based on Casualty Criterion WIA(1+) and a PAR of 4,503,258.

Table 31. Cumulative Casualties Occurring from Fallout from 10KT Ground Burst (IND), LIBN Scenario, All Personnel Unprotected and without Medical Treatment*

Casualty Description	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7	DAYS 8-14	DAYS 15-30	DAYS 31+
Fatalities										
KIA (Radiological)	0	0	0	0	0	0	0	0	0	0
DOW (Radiological)	0	0	0	0	0	0	0	0	7	43
Sum of Fatalities	0	0	0	0	0	0	0	0	7	43
WIA†										
R0§	0	0	74	74	74	74	74	0	0	0
R-0, C-1	226	671	0	0	0	0	0	0	0	0
R-0, C-2	0	0	0	36	0	0	0	0	0	0
R-1, C-1	445	74	0	0	0	0	0	0	0	0
R-1, C-2	0	0	36	0	36	36	36	0	0	0
R-2, C-0	0	0	0	0	0	0	0	74	74	0
R-2, C-1	0	36	0	0	0	0	0	0	0	0
R-2, C-3	0	0	0	0	0	0	0	36	0	0
R-3, C-0	0	0	0	0	0	0	0	0	0	74
R-3, C-1	117	7	0	0	0	0	0	0	0	0
R-3, C-2	0	0	7	7	7	7	7	0	0	0
R-3, C-3	0	0	0	0	0	0	0	0	36	0
R-4, C-3	0	0	0	0	0	0	0	7	0	0
Sum of WIA	788	788	117	117	117	117	117	117	110	74
RTD										
RTD	0	0	671	671	671	671	671	671	671	671

* Estimate is based on Casualty Criterion WIA(1+) and a PAR of 816.
† Any WIA row that has a population of zero is excluded from the table.
NOTE that rounding to nearest whole number may result in a “0” indication when a fractional casualty estimate less than 0.5 is made.

5. Step 4: Integrate the Casualty Estimate into the Course of Action Analyses

This analysis demonstrates the casualty estimation process described in AMedP-7.5. However, the casualty estimate is just one of the aspects considered by commanders and staff in planning an operation against an enemy, or in an area, that poses a radiological or nuclear threat. The final step in the casualty estimation process is to integrate the casualty estimate into the course of action analyses in the military planning process. One way to do this is to compare the casualties resulting from various courses of action, and provide recommendations related to operational capability, personnel replacement, and medical logistics.

For the nuclear weapon threat against the LIBN, six different combinations of threats and courses of action were considered. A summary of the different types of casualties that would result from these combinations is provided in Table 32.

Table 32. Casualty Summary for a 10KT Nuclear Weapon Challenge to the LIBN

Scenario	Total KIA	Total DOW	Total WIA	Total CONV	Total RTD
1-N-Grd-0	21	569	795	N/A	203
1-N-Grd-P	21	562	725	N/A	140
1-N-Grd-M	21	520	725	111	94
1-N-Grd-G	21	513	725	118	94
1-N-Air-0	14	802	802	N/A	0
1-N-Air-G	14	748	670	78	0

For the radiological weapon threat against the LIBN, five different radiological threats were considered, with no variation in the courses of action beyond providing no protection or medical treatment. A summary of the different types of casualties that would result from these threats is provided in Table 33.

Table 33. Casualty Summary for a Radiological Challenge to the LIBN

Scenario	Total KIA	Total DOW	Total WIA	Total CONV	Total RTD
1-CsRDD-0	0	0	251	N/A	244
1-SrRDD-0	0	0	0	N/A	0
1-AmRDD-0	0	0	0	N/A	0
1-PuRDD-0	0	0	0	N/A	0
1-Fallout-0	0	43	788	N/A	671

For the nuclear or radiological weapon threat against the civilian population, the very simplified assumption was made that the population would be unprotected and medical care would not be available in a timely manner. A summary of the different types of casualties that would result under these conditions is provided in Table 34.

Table 34. Casualty Summary for a Nuclear or Radiological Challenge to the Civilian Population Scenario

Scenario	Total KIA	Total DOW	Total WIA	Total CONV	Total RTD
2-N-Grd-0	48,623	335,517	581,889	N/A	228,977
2-CsRDD-0	0	35,129	374,154	N/A	266,333

A. Operational Impacts

For a 10KT nuclear weapon threat, the operational conclusion is that this battalion would be rendered ineffective. Without protection, either the surface burst or low air burst results in estimates that all personnel become casualties, either WIA or KIA. With protection, between 9% and 16% of the unit is unaffected. With protection and medical care, up to about 25% of the unit will survive their wounds. In none of these courses of action does enough of the unit remain sufficiently effective to succeed in any operational mission. The operational recommendation to the commander is that this mission not be pursued if the unit is likely to be attacked with a nuclear weapon. If possible, countermeasure missions, heightened signals intelligence and security, and use of scouts far forward to suppress the nuclear threat should be pursued. In addition, alternatives to normal operational procedures, such as unit dispersal and nuclear protective posture, should be considered to further mitigate the nuclear weapon effects.

For the radiological threats considered, two resulted in estimates of significant degradation of the unit effectiveness. The ^{137}Cs RDD resulted in about one-third of the unit exhibiting the symptoms of the Acute Radiation Syndrome (ARS), while effectively the entire unit (97%) was similarly affected by the fallout. Although a large fraction of the personnel affected recover from their wounds and are reclassified as RTD by the third day, the unit would not be combat effective during this period; reconstitution will also be a

problem, given personnel exposure and equipment contamination. This case would make an interesting policy discussion on the disposition of those who are RTD and the unit support requirements. Certainly, the radiation exposure status (RES) of the unit would be classified as RES 3 (>150cGy) for these two attacks. The use of ^{90}Sr as the radioisotope of interest produced no casualties in the estimate, nor did excursions with ^{241}Am or ^{238}Pu. Although marginally better than a nuclear attack, the operational recommendation to the commander is that if the RDD threat is specifically ^{137}Cs, the use of a ^{137}Cs RDD would render the unit operationally ineffective and an alternative course of action for this mission should be pursued. As with the nuclear scenarios, countermeasure missions to suppress this threat should be pursued prior to the enemy use of a ^{137}Cs RDD. In addition, alternatives to normal operational procedures should be considered. The other RDD threats are negligible from an operational perspective.

The civilian population scenario has 1,116,207 personnel (300,000 "tourists" and 816,207 "residents") considered. The military could credibly be called in to provide support in the response phase after the use of a nuclear or radiological device. With that mission, it is clear that providing medical care and basic shelter to hundreds of thousands of casualties will probably require more than can be provided, even by the entire DOD health care system. Even mortuary support could be overwhelmed, with 48,623 prompt fatalities expected from the IND. Nonetheless this event would likely result in an "all of government" response. The senior DOD leaders, both military and civilian, would have to carefully balance the clear need for medical and logistical support with the strong potential for compromising the military's ability to respond to other operational requirements.

B. Personnel Impacts

There are 816 personnel considered in the LIBN scenario. All of the nuclear and radiological exposures, except for the ^{90}Sr, ^{241}Am and ^{238}Pu RDDs, resulted in the loss of the unit as an operational asset. Missions that risk the exposure of this unit to nuclear or radiological events should be pursued only under conditions of the utmost urgency. Countermeasure missions to suppress this threat should be pursued prior to the enemy use.

Regarding the civilian scenario, this is a support mission after the event (consequence management). The total number of military personnel that would be called upon to provide support could very likely be so many as to compromise operational readiness, at least for those capabilities required in response. The recommendation to minimize operational compromise is to prioritize the response to Reserve Component and National Guard units proximate to the event.

C. Medical Impacts

For the military scenarios, the medical requirements resulting from these nuclear and radiological events exceed the capabilities of any deployed Role 3 medical treatment

facility (combat support hospital = 245 beds). Concur with the operational recommendation that missions that risk exposure of this unit to nuclear or radiological events should not be pursued, or pursued only under conditions of the utmost urgency. Countermeasure missions to suppress this threat should be pursued prior to the enemy use. There are no effective medical countermeasures that could be put in place to mitigate the casualty estimates. The commander should consider moving medical treatment or evacuation assets to the theater to address this medical requirement.

6. Conclusions

This analysis sought to “identify and illustrate the applicability of using current casualty estimation methodologies to develop planning parameters for tactical and terroristic threats of the use of radiation exposure devices (REDs), radiation dispersal devices (RDDs), and improvised nuclear devices (INDs), as well as conventional nuclear weapons.”

The NATO casualty estimation methodology proved capable of estimating the numbers, types, and timing of casualties in all scenarios. The resulting casualty estimates do provide a planner with the necessary figures to consider for a “tactical and terroristic threats of the use of” radiological or weapons. Depending upon the scenario, the casualty estimates varied from none to 100% of the population considered. In almost all cases in which casualties were present, the numbers of casualties were such that they pose a considerable or catastrophic operational challenge.

Appendix A: Light Infantry Battalion Task Force (LIBN) in Defense of an Airfield

Icon #	X-Coord (km)	Y-Coord (km)	Crew (# of persons)	Location	Structure or Vehicle	Neutron Radiation Transmission Factor	Gamma Radiation Transmission Factor	Blast Shielding Protection Factor	Thermal Transmission Probability, Unwarned
1	-0.350	0.873	4	1-A Co Area	TOC	1	1	1	1
2	0.054	0.430	4	1-B Co Area	TOC	0.33	0.10	1	0.05
3	-0.072	1.124	1	1 Bn CP	Hangar	0.75	0.64	1	0.75
4	-0.313	1.577	4	1-C Co Area	TOC	1	1	1	1
5	-0.049	1.119	1	1 Bn CP	Hangar	0.33	0.10	1	0.05
6	-0.541	0.658	7	1-A Co Area	Foxhole	0.33	0.10	1	0.05
7	-0.707	0.724	7	1-A Co Area	Foxhole	1	1	1	1
8	-0.783	0.874	7	1-A Co Area	Dismounted	1	1	1	1
9	-0.706	1.060	7	1-A Co Area	Dismounted	1	1	1	1
10	-0.270	0.873	7	1-A Co Area	Dismounted	0.82	0.37	1	1
11	-0.309	0.969	7	1-A Co Area	Foxhole	0.33	0.10	1	0.05
12	-0.240	0.555	7	1-A Co Area	Foxhole	1	1	1	1
13	-0.301	0.620	7	1-A Co Area	Dismounted	0.33	0.10	1	0.05
14	-0.386	0.741	7	1-A Co Area	Foxhole	1	1	1	1
15	-0.419	0.820	7	1-A Co Area	Foxhole	0.33	0.10	1	0.05
16	-0.181	0.632	7	1-A Co Area	Foxhole	0.33	0.10	1	0.05
17	-0.246	0.748	7	1-A Co Area	Dismounted	0.82	0.37	1	1
18	-0.486	0.996	7	1-A Co Area	Foxhole	1	1	1	1
19	-0.530	1.106	7	1-A Co Area	Dismounted	1	1	1	0.25

Icon #	X-Coord (km)	Y-Coord (km)	Crew (# of persons)	Location	Structure or Vehicle	Neutron Radiation Transmission Factor	Gamma Radiation Transmission Factor	Blast Shielding Protection Factor	Thermal Transmission Probability, Unwarned
20	-0.586	1.276	7	1-A Co Area	Foxhole	1	1	1	1
21	-0.539	1.365	7	1-A Co Area	Dismounted	1	1	1	1
22	-0.448	1.109	7	1-A Co Area	Dismounted	1	1	1	0.25
23	-0.457	1.251	7	1-A Co Area	Dismounted	0.33	0.10	1	0.05
24	0.461	0.344	7	1-B Co Area	Foxhole	0.82	0.37	1	1
25	0.328	0.203	7	1-B Co Area	Foxhole	0.82	0.37	1	1
26	-0.021	0.161	7	1-B Co Area	Dismounted	0.82	0.37	1	1
27	-0.204	0.224	7	1-B Co Area	Dismounted	0.82	0.37	1	1
28	0.122	0.448	7	1-B Co Area	Foxhole	0.95	0.95	1	0.90
29	-0.004	0.414	7	1-B Co Area	Foxhole	1	1	1	1
30	0.332	0.531	7	1-B Co Area	Dismounted	0.82	0.37	1	1
31	0.352	0.457	7	1-B Co Area	Dismounted	0.82	0.37	1	1
32	0.414	0.459	7	1-B Co Area	Foxhole	0.33	0.10	1	0.05
33	0.189	0.354	7	1-B Co Area	Dismounted	1	1	1	1
34	0.223	0.498	7	1-B Co Area	Foxhole	0.33	0.10	1	0.05
35	0.135	0.407	7	1-B Co Area	Dismounted	0.82	0.37	1	1
36	-0.006	0.335	7	1-B Co Area	Dismounted	0.95	0.95	1	0.90
37	-0.132	0.345	7	1-B Co Area	Foxhole	0.95	0.95	1	0.90
38	-0.165	0.374	7	1-B Co Area	Foxhole	1	1	1	1
39	-0.190	0.400	7	1-B Co Area	Foxhole	1	1	1	1
40	-0.044	0.402	7	1-B Co Area	Dismounted	1	1	1	1
41	-0.088	0.449	7	1-B Co Area	Foxhole	0.82	0.37	1	1
42	-0.800	1.760	7	1-C Co Area	Dismounted	1	1	1	1

Icon #	X-Coord (km)	Y-Coord (km)	Crew (# of persons)	Location	Structure or Vehicle	Neutron Radiation Transmission Factor	Gamma Radiation Transmission Factor	Blast Shielding Protection Factor	Thermal Transmission Probability, Unwarned
43	-0.552	1.844	7	1-C Co Area	Foxhole	0.95	0.95	1	0.90
44	-0.410	1.814	7	1-C Co Area	Dismounted	1	1	1	1
45	-0.128	1.772	7	1-C Co Area	Foxhole	0.33	0.10	1	0.05
46	-0.404	1.603	7	1-C Co Area	Foxhole	1	1	1	1
47	-0.249	1.600	7	1-C Co Area	Foxhole	1	1	1	1
48	-0.562	1.514	7	1-C Co Area	Dismounted	1	1	1	0.25
49	-0.572	1.596	7	1-C Co Area	Foxhole	1	1	1	0.25
50	-0.542	1.676	7	1-C Co Area	Dismounted	1	1	1	1
51	-0.464	1.699	7	1-C Co Area	Foxhole	0.82	0.37	1	1
52	-0.457	1.513	7	1-C Co Area	Foxhole	1	1	1	0.25
53	-0.460	1.596	7	1-C Co Area	Dismounted	1	1	1	0.25
54	-0.391	1.716	7	1-C Co Area	Dismounted	1	1	1	1
55	-0.304	1.692	7	1-C Co Area	Dismounted	0.82	0.37	1	1
56	-0.205	1.663	7	1-C Co Area	Dismounted	0.72	0.82	1	0.25
57	-0.128	1.602	7	1-C Co Area	Dismounted	1	1	1	0.25
58	-0.364	1.626	7	1-C Co Area	Foxhole	0.72	0.82	1	0.25
59	-0.239	1.576	7	1-C Co Area	Dismounted	1	1	1	0.25
60	0.637	0.764	7	2-C Co Area	Foxhole	0.72	0.82	1	0.25
61	0.714	0.999	7	2-C Co Area	Dismounted	1	1	1	0.25
62	0.714	0.999	7	2-C Co Area	Foxhole	0.33	0.10	1	0.05
63	0.513	1.267	7	2-C Co Area	Dismounted	1	1	1	0.25
64	0.346	1.385	7	2-C Co Area	Foxhole	1	1	1	1
65	0.277	0.673	7	2-C Co Area	Dismounted	0.82	0.37	1	1

Icon #	X-Coord (km)	Y-Coord (km)	Crew (# of persons)	Location	Structure or Vehicle	Neutron Radiation Transmission Factor	Gamma Radiation Transmission Factor	Blast Shielding Protection Factor	Thermal Transmission Probability, Unwarned
66	0.284	0.740	7	2-C Co Area	Foxhole	0.75	0.64	1	0.75
67	0.296	0.863	7	2-C Co Area	Foxhole	0.95	0.95	1	0.05
68	0.234	0.980	7	2-C Co Area	Dismounted	0.33	0.10	1	0.05
69	0.154	1.215	7	2-C Co Area	Dismounted	0.12	0.15	1	0.25
70	0.076	1.304	7	2-C Co Area	Dismounted	0.33	0.10	1	0.05
71	0.037	1.405	7	2-C Co Area	Dismounted	1	1	1	1
72	-0.197	0.958	7	2-C Co Area	Foxhole	0.12	0.15	1	0.25
73	-0.197	0.958	12	1-A Co Area	4.2MTR	0.12	0.15	1	0.25
74	0.129	0.497	12	1-B Co Area	4.2MTR	0.75	0.64	1	0.25
75	-0.390	1.502	12	1-C Co Area	4.2MTR	0.12	0.15	1	0.25
76	-0.323	0.680	2	1-A Co Area	CHAPP	0.75	0.64	1	0.25
77	-0.541	1.166	2	1-A Co Area	CHAPP	0.75	0.64	1	0.75
78	0.349	0.574	2	1-B Co Area	CHAPP	0.12	0.15	1	0.25
79	0.004	0.481	2	1-B Co Area	CHAPP	0.33	0.10	1	0.05
80	-0.437	1.557	2	1-C Co Area	CHAPP	0.33	0.10	1	0.05
81	-0.053	1.708	2	1-C Co Area	CHAPP	1	1	1	1
82	0.289	0.796	2	2-C Co Area	CHAPP	1	1	1	0.25
83	0.025	1.402	2	2-C Co Area	CHAPP	1	1	1	0.25
84	-0.071	0.595	4	Barrier Road	M113	0.33	0.10	1	0.05
85	0.114	0.339	4	Barrier Road	M113	0.95	0.95	1	0.05
86	0.249	1.062	4	Barrier Road	M113	1	1	1	0.25
87	-0.291	1.889	4	Barrier Road	M113	1	1	1	0.25
88	-0.483	0.907	4	Barrier Road	M113	0.33	0.10	1	0.05

Icon #	X-Coord (km)	Y-Coord (km)	Crew (# of persons)	Location	Structure or Vehicle	Neutron Radiation Transmission Factor	Gamma Radiation Transmission Factor	Blast Shielding Protection Factor	Thermal Transmission Probability, Unwarned
89	-0.011	1.446	4	Mortar area	M106A2 4.2 inch Mortar	0.82	0.37	1	1
90	-0.065	1.475	4	Mortar area	M106A2 4.2 inch Mortar	0.95	0.95	1	0.05
91	-0.040	1.518	4	Mortar area	M106A2 4.2 inch Mortar	1	1	1	0.25
92	0.059	1.184	2	Cbt Trains	CBPS	0.72	0.82	1	0.25
93	0.047	1.501	4	Mortar area	M106A2 4.2 inch Mortar	0.72	0.82	1	0.25
94	-0.094	0.733	10	1-A Co Area	155mm SP howitzer	0.33	0.10	1	0.05
95	0.046	1.211	2	Cbt Trains	CBPS	0.72	0.82	1	0.25
96	-0.145	0.800	10	1-A Co Area	155mm SP howitzer	1	1	1	1
97	0.023	1.222	2	Cbt Trains	CBPS	0.33	0.10	1	0.05
98	-0.169	0.729	10	1-A Co Area	155mm SP howitzer	1	1	1	0.25
99	-0.270	1.059	10	1-A Co Area	155mm SP howitzer	1	1	1	1
100	-0.363	1.116	10	1-A Co Area	155mm SP howitzer	0.95	0.95	1	0.05
101	-0.246	1.169	10	1-A Co Area	155mm SP howitzer	0.72	0.82	1	0.25
102	-0.202	1.572	10	Cbt Trains	Tent	0.33	0.10	1	0.05
103	-0.339	1.226	10	Cbt Trains	5 ton van expansible	0.33	0.10	1	0.05

Icon #	X-Coord (km)	Y-Coord (km)	Crew (# of persons)	Location	Structure or Vehicle	Neutron Radiation Transmission Factor	Gamma Radiation Transmission Factor	Blast Shielding Protection Factor	Thermal Transmission Probability, Unwarned
104	0.092	1.077	4	2-C Co Area	Truck / Van	1	1	1	0.25
105	-0.378	1.322	10	Cbt Trains	5 ton van expansible	0.82	0.37	1	1
106	0.102	1.044	4	2-C Co Area	Dismounted	0.33	0.10	1	0.05
107	-0.408	1.393	10	Fld Trains	ReCovery Vehicle-Light/M578	0.72	0.82	1	0.25
108	0.079	1.121	1	1 Bn CP	Tent	0.72	0.82	1	0.25
109	-0.158	1.464	10	Fld Trains	5 ton van expansible	0.72	0.82	1	0.25
110	0.064	1.093	1	2-C Co Area	Dismounted	0.82	0.37	1	1
111	-0.117	1.364	10	Fld Trains	5 ton van expansible	0.72	0.82	1	0.25
112	0.185	0.655	3	2-C Co Area	Foxhole	0.33	0.10	1	0.05
113	0.244	0.812	4	1 Bn CP	Tent	0.72	0.82	1	0.25
114	0.214	0.883	4	1 Bn CP	Tent	0.72	0.82	1	0.25
115	0.235	0.639	10	2-C Co Area	ACE	0.33	0.10	1	0.05
116	0.210	0.699	10	2-C Co Area	ACE	1	1	1	1
117	0.062	0.819	1	2-C Co Area	Hangar	0.95	0.95	1	0.05
118	0.098	0.821	1	2-C Co Area	Hangar	0.95	0.95	1	0.05
119	0.072	0.794	1	2-C Co Area	Hangar	0.95	0.95	1	0.05
120	0.105	0.799	1	2-C Co Area	Foxhole	0.33	0.10	1	0.05
121	0.098	0.854	1	2-C Co Area	Foxhole	0.82	0.37	1	1
122	0.121	0.880	1	2-C Co Area	Dismounted	0.82	0.37	1	1

Icon #	X-Coord (km)	Y-Coord (km)	Crew (# of persons)	Location	Structure or Vehicle	Neutron Radiation Transmission Factor	Gamma Radiation Transmission Factor	Blast Shielding Protection Factor	Thermal Transmission Probability, Unwarned
123	0.131	0.859	1	2-C Co Area	Hangar	0.82	0.37	1	1
124	0.019	0.936	1	2-C Co Area	Hangar	0.28	0.10	1	0.75
125	-0.042	1.035	1	2-C Co Area	Control Tower	1	1	1	1
126	0.160	0.763	3	2-C Co Area	Truck / Van	1	1	1	1
127	0.147	0.768	4	2-C Co Area	Truck / Van	0.28	0.10	1	0.75
128	0.092	0.974	4	2-C Co Area	TOC	0.33	0.10	1	0.05
129	0.085	0.990	4	2-C Co Area	Truck / Van	1	1	1	1
130	0.079	1.002	4	1 Bn CP	Tent	0.82	0.37	1	1
131	0.002	1.027	2	2-C Co Area	Admin Bldg	0.33	0.10	1	0.05
132	0.010	1.046	1	2-C Co Area	Admin Bldg	1	1	1	1
133	0.016	1.034	1	2-C Co Area	Admin Bldg	0.33	0.10	1	0.05
134	-0.029	1.129	1	1 Bn CP	Hangar	0.33	0.10	1	0.05
135	0.052	1.178	2	Cbt Trains	CBPS	0.75	0.64	1	0.75
136	0.077	1.072	5	2-C Co Area	Foxhole	1	1	1	1
137	0.064	1.103	1	1 Bn CP	Tent	0.33	0.10	1	0.05
138	0.068	1.126	1	1 Bn CP	Tent	0.33	0.10	1	0.05
139	0.110	1.045	3	2-C Co Area	Foxhole	0.82	0.37	1	1
140	0.180	0.656	4	2-C Co Area	Dismounted	0.82	0.37	1	1
141	0.064	0.799	1	2-C Co Area	Hangar	0.33	0.10	1	0.05
142	0.097	0.801	1	2-C Co Area	Hangar	0.33	0.10	1	0.05
143	0.086	0.822	1	2-C Co Area	Hangar	0.33	0.10	1	0.05
144	0.112	0.878	1	2-C Co Area	Truck / Van	1	1	1	0.25
145	0.011	0.936	1	2-C Co Area	Hangar	1	1	1	1

Icon #	X-Coord (km)	Y-Coord (km)	Crew (# of persons)	Location	Structure or Vehicle	Neutron Radiation Transmission Factor	Gamma Radiation Transmission Factor	Blast Shielding Protection Factor	Thermal Transmission Probability, Unwarned
146	0.019	0.918	1	2-C Co Area	Hangar	0.33	0.10	1	0.05
147	-0.055	1.030	1	2-C Co Area	Control Tower	0.33	0.10	1	0.05
148	0.167	0.764	3	2-C Co Area	Truck / Van	1	1	1	1
149	0.137	0.764	3	2-C Co Area	Foxhole	1	1	1	1
150	-0.049	1.117	1	1 Bn CP	Tent	0.33	0.10	1	0.05
151	0.096	0.997	6	2-C Co Area	TOC	0.33	0.10	1	0.05
152	0.092	0.966	1	2-C Co Area	Truck / Van	0.75	0.64	1	0.75
153	0.102	0.984	6	2-C Co Area	TOC	1	1	1	1
154	0.007	1.037	1	2-C Co Area	Admin Bldg	1	1	1	1
155	0.004	1.055	1	2-C Co Area	Admin Bldg	1	1	1	1

Appendix B: Technical Aspects of Estimating the Effective Radiological or Nuclear Challenge

This appendix describes some of the technical questions and modelling that must be addressed to estimate the effective radiological or nuclear challenge.

1. Nuclear Weapon Selection Process: Which weapons pose a threat?

Two weapon factors greatly influence how many casualties might result from the detonation of a nuclear weapon: yield and height of burst (HoB). There are other factors (such as weapon type, construction, atmospheric conditions, etc.) that might influence the casualty estimate, but yield and HoB have the most significant impact. Succinctly: The higher the yield, the more casualties might be expected, and the HoB must be in a relatively narrow band of interest (from near the surface of the ground to a low altitude above the ground) to produce significant casualties from the direct effects of a nuclear weapon.

a. Yield

The yield of the weapon (commonly represented by "W") is the measure of how much energy is released in the weapon detonation. It is typically expressed in kiloton (KT) or megaton (MT) equivalents of conventional high explosive (such as trinitrotoluene, or TNT). From a historical perspective, it is clear that 1940s technology is sufficient to produce a fission weapon in the 10-20 KT range (such as was detonated in Trinity, NM, or Hiroshima and Nagasaki, Japan, in 1945). Subsequent technological advances have allowed for that range to stretch from 0.01 KT to (perhaps) 100 MT[27].

For operational planning using the NATO CBRN casualty estimation methodology, an underlying assumption is that the planner is concerned with "tactical" nuclear weapons, designed to be used on a battlefield or other small area targets to influence battles and engagements. "Strategic" nuclear weapons tend to have higher yield, longer range delivery systems, and are used to achieve national or multinational (alliance or coalition) strategic security objectives.[28] Although some countries do not differentiate between tactical and strategic nuclear weapons, it may be a useful rule of thumb to divide the two categories at about 300 KT: above is strategic, below is tactical.

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[27] "Complete List of All U.S. Nuclear Weapons,". *http://nuclearweaponarchive.org*. 3 September 2007. Retrieved 10 December 2014.

[28] U.S. Department of Defense, Joint Chiefs of Staff, Department of Defense Dictionary of Military and Associated Terms, Joint Publication 1-02, 8 November 2010 (as amended through 15 November 2014), pp. 237 and 244.

Although there are as many as nine or ten countries with nuclear arsenals,[29] the threat from nuclear weapons is not limited to nuclear states. Terrorists seeking to unleash massive violence and destruction may climb the escalation ladder to the highest rungs: nuclear weapons. They may acquire fissile material by purchase, diversion, or force for the purpose of fabricating a crude nuclear bomb, known more formally as an "improvised nuclear device" (IND)[30]. It is generally assumed that successful INDs would have yields in the 10-20 KT range.[31]

b. Height of Burst

The immediate effects of nuclear detonation (radiation, blast and thermal), as well as the residual radiation, vary not just as a function of yield but also with the location of the point of burst in relation to the surface of the earth. For descriptive purposes, four types of burst are identified in the Handbook of Nuclear Weapon Effects (EM-1):[32]

1. Underground and underwater bursts (where the fireball does not intersect the surface);
2. Surface and near-surface bursts (where the fireball intersects the surface, and includes shallow-buried bursts);
3. Airbursts (where the fireball does not intersect the surface up to 30 km altitude);
4. High-altitude bursts (above 30 km).

Many variations and intermediate situations can arise in practice. This is not meant to be totally inclusive of all possible heights of burst, but the basic idea is that the effects of a nuclear detonation depend strongly on how far above, or below, the surface the detonation occurs.

From a casualty estimation perspective, a detonation that is so far below the surface that the explosion is completely contained underground (or underwater) is of little interest because no casualties result. Similarly, detonations so far above the surface that no casualties result are also of little interest. A surface burst, at or very near the ground, will produce the most residual radiation in the fallout debris that is lofted into the atmosphere and deposited downwind, while still resulting in significant immediate effects. The amount of fallout will decrease as the height of burst (HoB) increases, until the fireball resulting

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[29] The Nuclear Weapon Archive, *http://nuclearweaponarchive.org*. 3 September 2007. Retrieved 10 December 2014.

[30] Charles D. Ferguson and William C. Potter, *Improvised Nuclear Devices and Nuclear Terrorism*, The Weapon of Mass Destruction Commission, Report No. 2, Stockholm, Sweden, 2004, p. 1.

[31] Ferguson and Potter, p. 5.

[32] *1996 Handbook of Nuclear Weapon Effects*, U.S. Department of Defense, Defense Threat Reduction Agency, Ft. Belvoir, VA, p. 1II-1.

from the detonation no longer contacts the ground. The radius of the fireball (in meters) for low-altitude, free-air bursts is given by $R_0 = 55W^{0.4}$, where R_0 is the fireball radius in meters and W is the yield in kilotons.[33] A detonation at HoB above this will still produce fallout, from the bomb materials, but the amount would be much less than if the fireball included the ground. As an alternative to selecting a "no fallout" HoB, the selection can be based on the optimization of the immediate effects at a specific range. The Personnel Risk and Casualty Criteria for Nuclear Weapons Effects (PRCC) (U) uses $HoB = 60W^{1/3}$ meters[34] for comparison of effects.

2. Radiological Weapon Selection Process: Which materials pose a threat?

"At the most fundamental level, radiological sources are used for three purposes: (1) to kill or otherwise alter organisms or tissue, (2) to generate energy on a localized and/or remote basis, or (3) to scan objects or provide other types of measurements."[35] Common industrial devices that use radionuclides include gauges, food irradiators, radiographic cameras, well logging devices, thickness measurement tools, brachytherapy devices, medical tracers, and radioisotope thermoelectric generators (RTGs). This list is by no means encompassing, but rather gives a general idea of the wide variety of sources that use radionuclides. Each radioactive source contains differing amounts, forms, and protective shielding of radionuclides. To aid nations in differentiating radioactive sources the IAEA published TECDOC-1344 entitled *Categorization of Radioactive Sources*.[36] The document provides an internationally standardized five-category system to classify dangerous radioactive sources. The IAEA defines a dangerous source as one "… that could, if not under control, give rise to exposure sufficient to cause severe deterministic effects."[37] The categories are based upon the magnitude of exposure and time required to cause deterministic effects.

A list of radionuclides of concern as possible sources for radiological weapons can be derived from various source listings of industrially applied radionuclides. From the U.S. regulatory perspective, the list of radionuclides of concern is published by the U.S. Nuclear Regulatory Commission (NRC),[38] For this analysis, the list of isotopes of concern was

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[33] *1996 Handbook of Nuclear Weapon Effects*, U.S. Department of Defense, Defense Threat Reduction Agency, Ft. Belvoir, VA, p. 6-30.

[34] *1999 Personnel Risk and Casualty Criteria for Nuclear Weapons Effects* (U), U.S. Army Nuclear and Chemical Agency, Ft. Belvoir, VA, p. A-1.

[35] Gregory J. Van Tuyle, Tiffany L. Strub, Harold A. O'Brien, Caroline F.V. Mason, Steven J. Gitomer, *Reducing RDD Concerns Related to Large Radiological Source Application*, Los Alamos National Laboratory, September 2003.

[36] IAEA TECDOC 1344 *Categorization of Radioactive Sources*, 2003.

[37] IAEA, *Preparedness and Response for a Nuclear or Radiological Emergency*, IAEA Safety Standards Series No. GSR-2, IAEA, Vienna, 2002.

[38] NRC, *Radionuclides of Concern*, Appendix A, 10CFR73, 2009.

derived from the IAEA[39], which includes the radionuclides on the NRC list and others. A complete list of the different practices associated with each isotope, and the range of activities for those practices, can be found in Appendix C. The list of radionuclides in Appendix D is all of the radionuclides in TECDOC-1344, which includes the NRC radionuclides of concern, how they are used ("practice") and some of their physical properties that are significant with respect to their use as a radiological weapon. The practices listed are those representative of the highest typical activity of that radionuclide.

3. Models

The NATO CBRN casualty estimation methodology[40] estimates casualties from nuclear and radiological weapons as a function of the degree to which an individual is exposed to nuclear effects or radiation from radioactive materials. To do this, it is first necessary to estimate the dose or insult(s) that the individual will experience. The NATO CBRN casualty estimation methodology specifies the units for expressing the dose or insult needed,[41] but the magnitude of that dose or insult will be determined through the use of various models that translate the concept of a weapon's use into an estimate of individual radiation dose, blast exposure, or flash burn. In order for IDA to "Identify and illustrate the applicability of using current casualty estimation methodologies to develop planning parameters for tactical and terroristic threats of the use of"[42] RED, RDD, IND, and conventional nuclear weapons it will be necessary to apply U.S. weapon effects models to the casualty estimation methodology (U.S. models used are described below).

a. Prompt Nuclear Effects Models

Prompt (or "initial") nuclear effects are those that are produced "simultaneously with the nuclear explosion"[43] and occur generally within the first minute. These include ionizing and thermal radiation, and air shock (blast). Ionizing radiation, in particular gamma and neutron radiation, are considered in the casualty estimation methodology as whole body dose (in units of gray (Gy)) or dose equivalent (in units of sievert (Sv)). Thermal radiation is expressed as thermal fluence (joules per square centimeter (J/cm^2)) and must be

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[39] IAEA 2006, *Dangerous Quantities of Radioactive Materials (D-values).*

[40] North Atlantic Treaty Organization (NATO), *AMedP-8(C): NATO Planning Guide for the Estimation of Chemical, Biological, Radiological, and Nuclear (CBRN) Casualties*, STANAG 2553 (Brussels: NATO, 2011).

[41] North Atlantic Treaty Organization (NATO), *AMedP-8(C): NATO Planning Guide for the Estimation of Chemical, Biological, Radiological, and Nuclear (CBRN) Casualties*, STANAG 2553 (Brussels: NATO, 2011), Table 2-4, p. 2-11.

[42] Project Order CA-6-3079 Amendment 5, CBRN Casualty Estimation and Support to the Medical CBRN Defense Planning & Response Project, signed 14 November 2013, Subproject 3, p. 4.

[43] 1977 Effects of Nuclear Weapons, p. 41.

translated into a burn injury (% Body Surface Area (%BSA) burned) to be considered for casualty estimation. Two different effects of air shock are considered: the overpressure of the blast wave passing through a body, and the dynamic pressure (wind) effects on that body. For the casualty estimation methodology, only the ability of the dynamic pressure to displace an individual (translational effects) is considered, and only for lethal injuries. The static overpressure is expressed, not surprisingly, as the pressure increase (in pascals (Pa)) above the ambient pressure.

The transport of ionizing radiation, in particular gamma and neutron radiation, has been extensively studied and modeled. The model used in this study, Version 6 of Air Transport of Radiation (ATR6)[44] was developed for the Defense Nuclear Agency (now the Defense Threat Reduction Agency (DTRA)). ATR6 uses inputs on weapon type, yield, height of burst, and horizontal range (among other inputs) to estimate gamma and neutron levels around a nuclear detonation.

Equations for the estimation of thermal fluence and air shock (blast) levels are concisely described in the *Calculational Tools Abstracted from DTRA's Effects Manual One (EM-1)*.[45] These are implemented in an Excel spreadsheet as a function of yield, height of burst, horizontal range, and meteorological factors such as air pressure and visibility. Thermal fluence is translated into flash burns under the assumption that an individual is wearing the equivalent of a battledress uniform (BDU) with a t-shirt, covering 88% of the body (12% is uncovered, equivalent to the hands and head).[46] This is assumed to be the equivalent of a tightly fitting utility uniform, such as the Army Combat Uniform (ACU).

b. Transport and Dispersion Model

The Hazard Prediction and Assessment Capability (HPAC) is a computer-based tactical and operational hazard prediction model capable of providing common representation of CBRN and toxic industrial chemicals/toxic industrial material hazard areas and effects. HPAC simulates the transport/dispersion through the atmosphere of hazardous materials resulting from CBRN releases. HPAC provides estimates of effects on the physical environment (e.g., surface deposition, airborne concentration).[47] HPAC will

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[44] F. Dolatshahi, D.C. Kaul and W.A. Woolson, "Technical and User's Manual, FORTRAN Edition, Version 6 of ATR (ATR6)," SAIC-90/1507, DNA-TR-91-165, Defense Nuclear Agency, Alexandria, VA, August 1991, Unclassified.

[45] "Handbook of Nuclear Weapons Effects," Calculational Tools Abstracted from DTRA's Effects Manual One (EM-1), John A. Northrop, Editor, Defense Threat Reduction Agency, Ft. Belvoir, VA, 2002.

[46] North Atlantic Treaty Organization (NATO), *AMedP-8(C): NATO Planning Guide for the Estimation of Chemical, Biological, Radiological, and Nuclear (CBRN) Casualties*, STANAG 2553 (Brussels: NATO, 2011), p. 2-26.

[47] *HPAC Overview Lesson 1*, HPA5 SP1-LI-1-HPAC Overview 2011.ppt, DTRA, Fort Belvoir, VA, 2011, p.5.

also provide estimates of the resultant effects of that environment on the exposed population, but this population effect (casualty) estimate does not follow the NATO CBRN casualty estimation methodology and will not be used in this analysis. Materials are transported and dispersed in the atmosphere using the Second-order Closure Integrated Puff (SCIPUFF) model. SCIPUFF is a Lagrangian transport and diffusion model with a wide range of application. SCIPUFF uses a collection of Gaussian puffs to represent an arbitrary three- dimensional, time-dependent concentration field, and incorporates an efficient scheme for splitting and merging puffs. Wind shear effects are modeled, and puffs are split when they grow too large for single point meteorology to be representative. These techniques allow the puff model to describe complex flow effects on dispersion, such as terrain-driven circulations.[48]

HPAC allows the estimation of surface deposition or airborne concentration for delayed radiation (fallout) or radiological weapons. It is necessary to specify the location (latitude, longitude, height above ground) as well as the magnitude of the weapon (yield of a nuclear weapon or IND, activity and explosive yield of a radiological dispersal weapon). To estimate the surface deposition or airborne concentration, it is necessary to specify "samplers" at the locations of interest, typically where personnel are located in the tactical or domestic population of interest. The samplers used in this analysis included those for Radiation Field Total Effective Dose Equivalent, Radiation Field All External Effective Dose, Isotope Ground Deposition Total Activity, and Isotope Air Concentration Total Activity. The All External Effective Dose can be used within the NATO CBRN casualty estimation methodology to directly estimate casualties, while the other samplers can be translated using the appropriate conversion factors to dose or dose equivalent for casualty estimation.

The dose for whole body radiation from radioactive material on the ground is estimated using HPAC groundshine samplers ("RAD:INT GRDSHINEEFF"). Cutaneous radiation dose is estimated from the groundshine and, under the assumption that skin may be contaminated to the same level as the ground, the activity concentration of radioactive material on the ground (TBq/m^2) using HPAC surface deposition samplers ("ISO_GRND TotalActivity"). The dose conversion factors for cutaneous dose from groundshine or contamination are provided in AMedP-7.5 (Table 3-2, also included in Appendix E).[49]

HPAC also requires that weather conditions be specified for transport and dispersion calculations. The weather selected was from HPAC's library of historical weather data, and was for the month of July (the date/time specified was 4 July 2014 at

[48] R. Ian Sykes, Stephen F. Parker, Douglas S. Henn, and Biswanath Chowdhury, *SCIPUFF Version 2.7 Technical Documentation*, Sage Management, Princeton, NJ, 2011, p. 1.

[49] AMedP-7.5, SD.3, Working Copy, 26 October 2015, 3-4.

noon). The resulting weather was for variable winds from the south for the operational and domestic scenario locations.

The duration and time interval of the transport and dispersion calculation was every (1.0) minute over a 48 hour period, except for calculations related to estimating the airborne activity. In those cases, the calculations were for every 5.0 seconds over 1 hour.

The estimates of fallout from a nuclear detonation used the HPAC “NWPN” scenario, with the default parameters as specified, except for the radiation type, latitude, longitude, yield, height of burst (HoB), and time of burst (ToB). The radiation type is selected as “Enhanced” to allow the use of radiation samplers. The appropriate latitude and longitude were specified for the operational and domestic scenario locations. The yield was specified as 10KT, and the yield HoB was specified as 0m to estimate fallout from the IND. The ToB was specified as noon on July 4 (14.07.04.12.00.00).

The explosive RDD estimates used the HPAC “RWPN” scenario, with parameters specified as:

- ^{137}Cs –1.1×10^{5} TBq (34 kg)
- ^{90}Sr – 740 TBq (150 g)
- ^{241}Am – 0.74 TBq (29.1 g)
- ^{238}Pu – 10 TBq (16 g)

Appendix C: Some Isotopes and Practices of Interest

Isotope	Practice	Activity in Practice (TBq) Minimum	Maximum	Typical
H-3	Tritium targets	1.10E-01	1.10E+00	2.60E-01
	Electron capture detectors	1.90E-03	1.10E-02	9.30E-03
	Lightning preventers	7.40E-03	7.40E-03	7.40E-03
P-32	Medical unsealed	2.20E-03	2.20E-02	2.20E-02
Fe-55	X ray fluorescence analyzers	1.10E-04	5.00E-03	7.40E-04
Co-57	Mossbauer Spectrometry	1.90E-04	3.70E-03	1.90E-03
	X ray fluorescence analyzers	5.60E-04	1.50E-03	9.30E-04
Co-60	Irradiators: sterilization and food preservation	1.90E+02	5.60E+05	1.50E+05
	Irradiators: self-shielded	5.60E+01	1.90E+03	9.30E+02
	Multi-beam teletherapy (gamma knife)	1.50E+02	3.70E+02	2.60E+02
	Teletherapy	3.70E+01	5.60E+02	1.50E+02
	Irradiators: blood/tissue	5.60E+01	1.10E+02	8.90E+01
	Industrial radiography	4.10E-01	7.40E+00	2.20E+00
	Calibration facilities	2.00E-02	1.20E+00	7.40E-01
	Brachytherapy - high/medium dose rate	1.90E-01	7.40E-01	3.70E-01
	Level gauges	3.70E-03	3.70E-01	1.90E-01
	Blast furnace gauges	3.70E-02	7.40E-02	3.70E-02
	Dredger gauges	9.30E-03	9.60E-02	2.80E-02
Ni-63	Electron capture detectors	1.90E-04	7.40E-04	3.70E-04
Ge-68	Poistron Emission Tomography (PET) checking	3.70E-05	3.70E-04	1.10E-04
Se-75	Industrial radiography	3.00E+00	3.00E+00	3.00E+00
Kr-85	Thickness gauges	1.90E-03	3.70E-02	3.70E-02
Sr-90	Radioisotopic thermoelectric generators (RTGs)	3.30E+02	2.50E+04	7.40E+02
	Calibration facilities	7.40E-02	7.40E-02	7.40E-02
	Thickness gauges	3.70E-04	7.40E-03	3.70E-03
	Brachytherapy: low dose-rate- eye plaques and permanent implants	7.40E-04	1.50E-03	9.30E-04
Mo-99	Diagnostic isotope generators	0.037	0.37	0.037
Pd-103	Brachytherapy: low dose-rate- eye plaques and permanent implants	1.10E-03	1.10E-03	1.10E-03
Ru/Rh-106	Brachytherapy: low dose-rate- eye plaques and permanent implants	8.10E-06	2.20E-05	2.20E-05
Cd-109	X ray fluorescence analyzers	1.10E-03	5.60E-03	1.10E-03
	Bone densitometry	0.00074	0.00074	0.00074

Isotope	Practice	Activity in Practice (TBq) Minimum	Maximum	Typical
I-125	Bone densitometry	0.0015	0.03	0.019
	Brachytherapy - low dose rate	1.50E-03	1.50E-03	1.50E-03
I-131	Medical unsealed	0.0037	0.0074	0.0037
Cs-137	Irradiators: sterilization and food preservation	1.90E+02	1.90E+05	1.10E+05
	Irradiators: self-shielded	9.30E+01	1.60E+03	5.60E+02
	Irradiators: blood/tissue	3.70E+01	4.40E+02	2.60E+02
	Teletherapy	1.90E+01	5.60E+01	1.90E+01
	Calibration facilities	5.60E-02	1.10E+02	2.20E+00
	Level gauges	3.70E-02	1.90E-01	1.90E-01
	Conveyor gauges	3.70E-03	1.50E+00	1.10E-01
	Brachytherapy - high/medium dose rate	1.10E-01	3.00E-01	1.10E-01
	Dredger gauges	7.40E-03	3.70E-01	7.40E-02
	Spinning pipe gauges	7.40E-02	1.90E-01	7.40E-02
	Well logging	3.70E-02	7.40E-02	7.40E-02
	Brachytherapy - low dose rate	3.70E-04	2.60E-02	1.90E-02
	Fill-level, thickness gauges	1.90E-03	2.40E-03	2.20E-03
	Moisture/density gauges	0.0003	0.00041	0.00037
	Density gauges	0.0003	0.00037	0.00037
Pm-147	Thickness gauges	1.90E-03	1.90E-03	1.90E-03
Gd-153	Bone densitometry	0.00074	0.056	0.037
Yb-169	Industrial radiography	9.30E-02	3.70E-01	1.90E-01
Tm-170	Industrial radiography	7.40E-01	7.40E+00	5.60E+00
Ir-192	Industrial radiography	1.90E-01	7.40E+00	3.70E+00
	Brachytherapy - high/medium dose rate	1.10E-01	4.40E-01	2.20E-01
	Brachytherapy - low dose rate	7.40E-04	2.80E-02	1.90E-02
Au-198	Brachytherapy - low dose rate	3.00E-03	3.00E-03	3.00E-03
Po-210	Static eliminators	0.0011	0.0041	0.0011
Ra-226	Brachytherapy - low dose rate	1.90E-04	1.90E-03	5.60E-04
	Moisture/density gauges	0.000074	0.00015	0.000074
	Lightning preventers	2.60E-07	3.00E-06	1.10E-06
Pu-238	Radioisotopic thermoelectric generators (RTGs)	1.00E+00	1.00E+01	1.00E+01
	Pacemakers	1.10E-01	3.00E-01	1.10E-01
Pu-239/Be	Calibration sources	7.40E-02	3.70E-01	1.10E-01
Am-241	Calibration facilities	1.90E-01	7.40E-01	3.70E-01
	Thickness gauges	1.10E-02	2.20E-02	2.20E-02

Isotope	Practice	Activity in Practice (TBq)		
		Minimum	Maximum	Typical
	Bone densitometry	0.001	0.01	0.005
	Fill-level, thickness gauges	4.40E-04	4.40E-03	2.20E-03
	Static eliminators	0.0011	0.0041	0.0011
	Lightning preventers	4.80E-05	4.80E-04	4.80E-05
Am-241/Be	Well logging	1.90E-02	8.50E-01	7.40E-01
	Research reactor startup sources	7.40E-02	1.90E-01	7.40E-02
	Moisture detectors	1.90E-03	3.70E-03	1.90E-03
	Moisture/density gauges	0.00037	0.0037	0.0019
Cm-244	Thickness gauges	7.40E-03	3.70E-02	1.50E-02
Cf-252	Brachytherapy - low dose rate	3.10E-03	3.10E-03	3.10E-03
	Conveyor gauges	1.40E-03	1.40E-03	1.40E-03
	Well logging	1.00E-03	4.10E-03	1.10E-03
	Moisture/density gauges	1.1E-06	2.6E-06	2.2E-06

Appendix D: Isotopes Considered as Potential Radiological Weapons

Isotope	Symbol	Practice	Half-Life	Radiation Type	Primary Form
Hydrogen-3 (Tritium)	^{3}H	Tritium targets	12.32 y	β	Liquid
Phosphorus-32	^{32}P	Medical (unsealed)	14.3 d	β	Powder
Iron-55	^{55}Fe	X ray fluorescence analyzers	2.70 y	X-ray	Liquid
Cobalt-57	^{57}Co	Mossbauer spectrometry	270.9 d	β and γ	Metal Foil
Cobalt-60	^{60}Co	Irradiators: sterilization and food preservation	5.27 y	β and γ	Metal (slugs or pellets)
Nickel-63	^{63}Ni	Electron capture detectors	96 y	β	Metal Foil
Germanium-68	^{68}Ge	Positron Emission Tomography (PET) checking	271 d	X-ray and γ (Ga-68 daughter)	Epoxy mixture
Selenium-75	^{75}Se	Industrial radiography	120 d	γ	Metal compound, pellets
Krypton-85	^{85}Kr	Thickness gauges	10.72 y	β and γ	Gas
Strontium-90	^{90}Sr	Radioisotopic thermoelectric generators (RTGs)	29.1 y	β	Metal Oxide Ceramic
Molybdenum-99	^{99}Mo	Diagnostic isotope generators	2.75 d	β	Metal oxide
Palladium-103	^{103}Pd	Brachytherapy: low dose-rate- eye plaques and permanent implants	17 d	γ	Resin Beads in metal capsule
Ruthenium-106/ Rhodium	$^{106}Ru/Rh$	Brachytherapy: low dose-rate- eye plaques and permanent implants	367 d	β	Metal Foil
Cadmium-109	^{109}Cd	X ray fluorescence analyzers	453 d	e^{-} and γ	Metal
Iodine-125	^{125}I	Brachytherapy: low dose-rate	60.1 d	X-ray and γ	Solid/salt
Iodine-131	^{131}I	Medical (unsealed)	8.04 d	β and γ	Solid/salt

Isotope	Symbol	Practice	Half-Life	Radiation Type	Primary Form
Caesium-137	^{137}Cs	Irradiators: sterilization and food preservation	30.17 y	β and γ	Pressed Powder
Promethium-147	^{147}Pm	Thickness gauges	2.62 y	β	Metal
Gadolinium-153	^{153}Gd	Bone densitometry	242 d	β and γ	Solid
Ytterbium-169	^{169}Yb	Industrial radiography	32.0 d	ε	Metal
Thulium-170	^{170}Tm	Industrial radiography	129 d	β	Metal
Iridium-192	^{192}Ir	Industrial radiography	74.0 d	β and γ	Metal
Gold-198	^{198}Au	Brachytherapy - low dose rate	2.69 d	β	Metal
Polonium-210	^{210}Po	Static eliminators	138 d	α	Metal foil
Radium-226	^{226}Ra	Brachytherapy - low dose rate	1600 y	α	Salt
Plutonium-238	^{238}Pu	Radioisotopic thermoelectric generators (RTGs)	87.7 y	α	Metal oxide ceramic
Plutonium-239/ Beryllium	$^{239}Pu/Be$	Calibration sources	24390 y	n	Intermetallic compound
Americium-241	^{241}Am	Calibration facilities	432.2 y	α and γ	Pressed ceramic powder (oxide)
Americium-241/ Beryllium	$^{241}Am/Be$	Well logging	432 y	n	Compressed powder
Curium-244	^{244}Cm	Thickness gauges	18.1 y	α	Solid
Californium-252	^{252}Cf	Brachytherapy - low dose rate	2.64 y	n	Metal Oxide Ceramic

Appendix E: Radiological and Nuclear Human Response Parameters

Tables excerpted from AMedP-7.5, NATO Planning Guide for the Estimation of CBRN Casualties, Study Draft 3 (Working Copy, 11 September 2015)

AMedP-7.5 Table 3-1, Suggested Dose Conversion Factors for RDDs for Selected Isotopes (Daughter Products Included)* [50]

Isotope*	Cloudshine [(Gy/hr)/(TBq/m³)]		Groundshine [(Gy/hr)/(TBq/m²)]		Skin Contamination [(Gy/hr)/(TBq/m²)]	Inhalation [Gy/TBq]
	Whole-Body ($Z_{RDD,wb,cld,r}$)	Cutaneous ($Z_{RDD,cut,cld,r}$)	Whole-Body ($Z_{RDD,wb,grd,r}$)	Cutaneous ($Z_{RDD,cut,grd,r}$)	Cutaneous ($Z_{RDD,cut,s,r}$)	Whole-Body ($Z_{RDD,wb,ih,r}$)
^{60}Co†	6.4×10^{2}	7.3×10^{2}	8.5×10^{0}	9.9×10^{0}	7.8×10^{1}	7.2×10^{2}
^{90}Sr§	3.8×10^{-2}	4.6×10^{1}	1.0×10^{-3}	5.0×10^{-1}	3.5×10^{2}	3.7×10^{3}
^{99}Mo§	3.7×10^{1}	1.6×10^{2}	5.3×10^{-1}	1.4×10^{-1}	1.9×10^{2}	2.0×10^{2}
^{125}I†	2.6×10^{0}	7.0×10^{0}	1.5×10^{-1}	4.1×10^{-1}	2.1×10^{0}	1.5×10^{1}
^{131}I†	9.2×10^{1}	1.5×10^{2}	1.4×10^{0}	2.3×10^{0}	1.6×10^{2}	6.1×10^{1}
^{137}Cs†	1.5×10^{2}	2.3×10^{2}	2.1×10^{0}	6.9×10^{0}	1.6×10^{2}	7.9×10^{2}
^{192}Ir†	2.0×10^{2}	2.8×10^{2}	2.9×10^{0}	4.4×10^{0}	1.9×10^{2}	4.3×10^{2}
^{226}Ra‡	1.6×10^{0}	2.4×10^{0}	2.3×10^{-2}	2.9×10^{-2}	0	2.2×10^{3}
^{238}Pu‡	2.5×10^{-2}	2.1×10^{-1}	3.0×10^{-3}	3.5×10^{-2}	3.7×10^{-1}	1.4×10^{4}
^{241}Am†	4.1×10^{0}	6.5×10^{0}	9.9×10^{-2}	3.0×10^{-1}	1.9×10^{0}	7.4×10^{3}
^{252}Cf¥	2.5×10^{-2}	1.6×10^{-1}	2.6×10^{-3}	2.1×10^{-2}	3.2×10^{-1}	3.3×10^{4}

* Values in this table were converted from units of Sievert (equivalent dose) to gray (absorbed dose) assuming a relative biological effectiveness (RBE) of 1. For cloudshine, the effective dose was multiplied by 1.4 to estimate ambient dose. The source of the inhalation factors states that they are for red marrow, not whole-body, but whole-body values are not available.

† Primarily a gamma emitter.

§ Primarily a beta emitter.

‡ Primarily an alpha emitter.

¥ Primarily a neutron emitter.

AMedP-7.5 Table 3-2, Suggested Conversion Factors for Fallout[51]

[50] AMedP-7.5, SD.3, Working Copy, 26 October 2015, 3-3.

[51] AMedP-7.5, SD.3, Working Copy, 26 October 2015, 3-4.

Time After Detonation	Groundshine* ($Z_{FO,cut,grd\text{-}\beta}$) [(Gy from β)/Gy from γ)]	Skin Contamination† ($Z_{FO,cut,s}$) [(Gy/hr)/(TBq/m^2)]
0.5 hours	9.6	N/A
1 hour	8.2	2.62×10^{-7}
2 hours	7.8	2.59×10^{-7}
4 hours	9.5	2.59×10^{-7}
6 hours	11.7	2.59×10^{-7}
12 hours	13.7	2.57×10^{-7}
24 hours (1 day)	10.9	2.54×10^{-7}
48 hours (2 days)	8.2	2.49×10^{-7}
72 hours (3 days)	6.7	2.46×10^{-7}
168 hours (1 week)	5.0	2.41×10^{-7}
336 hours (2 weeks)	5.3	2.41×10^{-7}
720 hours (1 month)	6.7	2.43×10^{-7}
1440 hours (2 months)	8.5	2.41×10^{-7}
2880 hours (4 months)	9.6	2.38×10^{-7}
4320 hours (6 months)	11.0	2.38×10^{-7}
6480 hours (9 months)	16.0	2.41×10^{-7}
8760 hours (1 year)	26.5	2.41×10^{-7}
17,520 hours (2 years)	88.1	2.43×10^{-7}

* For bare skin exposed to mixed fission products, 120 cm above ground.

† For mixed fission products and a basal cell layer depth of 40 μm.

AMedP-7.5 Table 4-49, Cutaneous Radiation Dose Ranges[52]

Dose Range	Description
< 2	No observable injury
2 – < 15	12 hours to 5 weeks post exposure: erythema, slight edema, possible increased pigmentation; 6 to 7 weeks post exposure: dry desquamation
15 – < 40	Immediate itching; 1 to 3 weeks post exposure: erythema, edema; 5 to 6 weeks post exposure: subcutaneous tissue edema, blisters, moist desquamation; late effects (> 10 weeks)
40 – < 550	Immediate pain, tingling for 1 to 2 days; 1 to 2 weeks post exposure: erythema, blisters, edema, pigmentation, erosions, ulceration, severe pain; severe late effects (> 10 weeks)
≥ 550	Immediate pain, tingling, swelling; 1 to 4 days post exposure: blisters, early ischemia, substantial pain; tissue necrosis within 2 weeks, substantial pain

[52] AMedP-7.5, SD.3, Working Copy, 26 October 2015, 4-61.

AMedP-7.5 Table 4-50, Cutaneous Radiation Injury Profiles[53]

Time Point (hr)	Dose Range			
	2 – < 15 Gy	15 – < 40 Gy	40 – < 550 Gy	≥ 550 Gy
0.1	0	0	0	1
1	0	0	1	1
8	0	1	1	1
10	1	1	1	1
24	1	1	1	2
48	0	0	2	2
192	0	0	3	3

AMedP-7.5 Table 4-51, Cutaneous Radiation Medical Treatment Outcome Reporting[54]

Dose Range (Gy)	DOW*	CONV*	RTD*
2 – < 15	0%	0%	Day 3: 100%
15 – < 40	0%	0%	Day 3: 100%
40 – < 550	0%	Day 3: 100%	0%
≥ 550	0%	Day 3: 100%	0%

* Reported values indicate the fraction that changes status on a given day; they are not cumulative.

AMedP-7.5 Table 4-52, Whole-Body Radiation Dose Ranges[55]

Dose Range (Gy)	Description
< 1.25	No observable injury
1.25 – < 3	A slight decrease in white blood cell and platelet count with possible beginning symptoms of bone marrow damage; survival is > 90% unless there are other injuries
3 – < 4.5	Moderate to severe bone marrow damage occurs; lethality ranges from $LD_{5/60}$ to $LD_{50/60}$; these patients require greater than 30 days recovery, but other injuries would increase the injury severity and likelihood of death
4.5 – < 8.3	Severe bone marrow damage occurs; lethality ranges from $LD_{50/60}$ to $LD_{99/60}$; death occurs within 3.5 to 6 weeks with the radiation injury alone but is accelerated with other injuries; with other injuries death may occur within 2 weeks
≥ 8.3	Bone marrow pancytopenia and moderate intestinal damage occur including diarrhea; death is expected within 2 to 3 weeks; with other injuries death may occur within 2 weeks; at higher doses, combined gastrointestinal and bone marrow damage occur with hypotension and death is expected within 1 to 2.5 weeks or if other injuries are also present, within 6 days

AMedP-7.5 Table 4-53, Whole-Body Radiation Injury Profiles[56]

[53] AMedP-7.5, SD.3, Working Copy, 26 October 2015, 4-61.

[54] AMedP-7.5, SD.3, Working Copy, 26 October 2015, 4-61.

[55] AMedP-7.5, SD.3, Working Copy, 26 October 2015, 4-62.

[56] AMedP-7.5, SD.3, Working Copy, 26 October 2015, 4-62.

Time Point (hr)	Dose Range			
	1.25 – < 3 Gy	3 – < 4.5 Gy	4.5 – < 8.3 Gy	≥ 8.3 Gy
0.3	0	0	1	3
0.7	0	0	2	3
2	0	2	3	3
3	1	2	3	3
5	1	3	3	3
8	1	2	3	3
24	0	1	2	3
30	0	0	2	3
48	0	0	1	3
72	0	0	0	3
96	0	0	1	3
192	0	2	2	4
336	0	2	3	4
720	0	3	4	4

AMedP-7.5 Table 4-54, Whole-Body Radiation Medical Treatment Outcome Reporting[57]

Dose Range (Gy)	DOW*	CONV*	RTD*
1.25 – < 3	0%	Day 2: 100%	0%
For Treatment Excluding Granulocyte-Colony Stimulating Factor (G-CSF)			
3 – < 6.8	0%	Day 30: 100%	0%
≥ 6.8	Rad: See Equation 4-32 Nuclear: 100%†	Rad: Day 30: 100% of WIAs that do not DOW	0%
For Treatment Including G-CSF			
3 – < 8.5	0%	Day 30: 100%	0%
≥ 8.5	Rad: See Equation 4-32 Nuclear: 100%†	Rad: Day 30: 100% of WIAs that do not DOW	0%

* Reported values indicate the fraction that changes status on a given day; they are not cumulative.

[57] AMedP-7.5, SD.3, Working Copy, 26 October 2015, 4-62.

AMedP-7.5 Table 4-55, Primary Nuclear Blast Insult Ranges[58]

Insult Range (kPa)	Description
< 50	No observable injury
50 – < 140	Eardrum rupture in 50%; threshold lung damage; threshold gastrointestinal damage
140 – < 240	Burdening level lung damage in 50%; burdening level tympanic membrane rupture in 90%
240 – < 290	Burdening level lung damage in 90%; lethality in 10%
≥ 290	Lethality in ≥ 50%

AMedP-7.5 Table 4-56, Primary Nuclear Blast Injury Profiles[59]

Time Point (hr)	Insult Range			
	50 – < 140 kPa	140 – < 240 kPa	240 – < 290 kPa	≥ 290 kPa
0.25	2	3	3	4*
30	2	2	3	
40	1	2	3	
192	0	1	3	
336	0	1	2	
408	0	0	1	
720	0	0	0	

* According to the default value for $T_{death\text{-}CN\text{-}SL4}$, death would be modeled at this point.

AMedP-7.5 Table 4-57, Primary Nuclear Blast Medical Treatment Outcome Reporting[60]

Insult Range (kPa)	DOW*	CONV*	RTD*
50 – < 140	0%	0%	Day 8: 100%
140 – < 240	0%	0%	Day 22: 100%
240 – < 290	0%	0%	Day 36: 100%
If $T_{MTF} \leq T_{death\text{-}CN\text{-}SL4}$			
≥ 290	Day 2: 23%	Day 43: 77%†	0%

Note: since this table applies to *primary* blast injuries, modeling of lethal tertiary effects, as described in section 4.4.3.4, is not affected by the availability of medical treatment.

Note: If $T_{MTF} > T_{death\text{-}CN\text{-}SL4}$, icons in the ≥ 290 kPa insult range are KIA, so this table is not needed to estimate their outcome.

* Reported values indicate the fraction that changes status on a given day; they are not cumulative.

† In the personnel status table, these individuals are reported as WIA(3) on Day 2 and remain there until becoming CONV.

58 AMedP-7.5, SD.3, Working Copy, 26 October 2015, 4-67.

59 AMedP-7.5, SD.3, Working Copy, 26 October 2015, 4-67.

60 AMedP-7.5, SD.3, Working Copy, 26 October 2015, 4-67.

AMedP-7.5 Table 4-60, Thermal Fluence Insult Ranges[61]

Insult Range (%BSA)	Description*
< 1	No observable injury†
1 – < 10	1st, 2nd and possible 3rd degree burns; electrolyte imbalance; pain
10 – < 20	Upper GI discomfort; 1st, 2nd and possible 3rd degree burns; electrolyte imbalance; increased pain
20 – < 30	Upper GI discomfort; 1st, 2nd and possible 3rd degree burns; fluid loss; decreased renal blood flow; compromise of the immune system; pain; lethality in 10%
≥ 30	Upper GI discomfort; 2nd and 3rd degree burns; hypovolemia; decreased renal blood flow; shock resulting from blood pressure decrease; cardiac distress; toxemia; multiple organ failure; lethality in ≥ 50%

* Estimation of burn lethality is approximate.

† < 1 %BSA may include a larger area of 1st degree burns.

AMedP-7.5 Table 4-61, Thermal Fluence Injury Profiles[62]

Time Point (hr)	Insult Range			
	1 – < 10 %BSA	10 – < 20 %BSA	20 – < 30 %BSA	≥ 30 %BSA
0.1	1	2	3	3
24	1	2	3	4*
48	2	2	3	
336	0	1	3	

* According to the default value for $T_{death\text{-}CN\text{-}SL4}$, death would be modeled at this point.

AMedP-7.5 Table 4-62, Thermal Fluence Medical Treatment Outcome Reporting[63]

Insult Range (%BSA)	DOW*	CONV*	RTD*
1 – < 15	0%	0%	Day 22: 100%
15 – < 30	0%	Day 36: 50%	Day 36: 50%
30 – < 45	Day 9: 25%	Day 43: 75%	0%
≥ 45	Day 7: 75%	Day 50: 25%	0%

* Reported values indicate the fraction that changes status on a given day; they are not cumulative.

[61] AMedP-7.5, SD.3, Working Copy, 26 October 2015, 4-72.

[62] AMedP-7.5, SD.3, Working Copy, 26 October 2015, 4-72.

[63] AMedP-7.5, SD.3, Working Copy, 26 October 2015, 4-72.

Appendix F: Illustrations

Appendix G: References

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Appendix H: Definitions

Note: The information in this section was taken from the websites of the following organizations: Health Physics Society, Nuclear Regulatory Commission, Centers for Disease Control, International Atomic Energy Association, etc. None of the definitions contained herein represent original work by the author of this study.

Absorbed dose: Absorbed dose is used for purposes of radiation protection and assessing dose or risk to humans in general terms. Absorbed dose is the amount of radiation absorbed in an organ or tissue (i.e., the amount of radiation energy that has been left in cells, tissues, or organs). Absorbed dose is usually defined as energy deposited (joule) per unit of mass (kilogram). See gray and rad.

Acute Radiation Syndrome (ARS): ARS is a serious illness that can happen when a person is exposed to very high levels of radiation, usually over a short period of time.[64]

Becquerel: Becquerel (Bq) is the unit in the International System of Units to replace the curie. It is based upon the radioactive decay rate of the radionuclide. One Bq is equal to one disintegration per second (dps).

Curie: Curie (Ci) is the traditional unit used to describe the amount of radioactive material present or strength of the source. See becquerel.

Deterministic Effect: A deterministic effect is a health effect of radiation for which generally a threshold level of dose exists above which the severity of the effect is greater for a higher dose. Such an effect is described as a 'severe deterministic effect' if it is fatal or life threatening or results in a permanent injury that decreases the quality of life.

Dose: Dose is a general term used to express how much radiation energy is deposited in something (a person or other material). The energy deposited can subsequently be expressed in terms of the absorbed, equivalent, committed, and/or effective dose based on the amount of energy absorbed and in what tissues.

Effective dose: Radiation exposures to the human body, whether from external or internal sources, can involve all or a portion of the body. The health effects of one unit of dose to the entire body are more harmful than the same dose to only a portion of the body. To enable radiation protection specialists to express partial-body exposures (and the accompanying doses) to portions of the body in terms of an equal dose to the whole body, the concept of effective dose was developed. Effective dose, then, is the dose to the whole body that would carry with it the same risk as a higher dose to only a portion of the body. As an example, 80 millisievert to the lungs is roughly the same potential detriment as 10 millisievert to the whole body based on this idea.

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[64] http://www.bt.cdc.gov/radiation/ars.asp.

Equivalent dose: Equivalent dose is a dose quantity used for radiation protection purposes that takes into account the chance that a type of radiation will cause an effect. Different types of radiation (alpha, beta, gamma) interact with human tissues differently, with some leaving a lot of energy in the tissue and others leaving very little energy in the tissue, and the energy that is left is what partially determines whether an effect will occur. Because of this, different types of radiation are assigned numbers based on how effective that type of radiation is at leaving its energy in the tissue, thus having more potential to cause an effect. By using equivalent dose, we are provided an indication of the potential for biological effects. From this, risk comparisons can be made between different types of radiation.

Exposure: Exposure is commonly used in reference to being around a radiation source, e.g., if you have a chest x ray, you are exposed to radiation. By definition, exposure is a measure of the amount of ionizations produced in air by photon radiation.

Gray: Gray (Gy) is the unit in the International System of Units used to describe absorbed radiation dose. It describes a specific amount of energy absorbed in a medium (human tissue, for example). In the traditional units, the rad describes absorbed radiation dose. One gray is equal to 100 rad.

Radiation: Radiation is energy given off by matter in the form of rays or high-speed particles… [Forces within an atom] work toward a strong, stable balance by getting rid of excess atomic energy (radioactivity). In that process, unstable nuclei may emit a quantity of energy, and this spontaneous emission is what we call radiation.[65]

Roentgen (R): Roentgen (R) is used to describe radiation exposure. This term describes the amount of ionization in air. In the International System of Units, the coulomb per kilogram ($C\ kg^{-1}$) describes radiation exposure. One roentgen is equal to $2.58 \times 10^{-4}\ C\ kg^{-1}$.

Sievert: Sievert (Sv) is the unit in the International System of Units to describe equivalent or effective radiation dose. One Sievert is equal to 100 rem. It is a unit that is the product of energy absorbed in human tissues and the quality of the radiation being absorbed (the ability of the radiation to cause damage). [66]

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[65] NRC, List of Definitions,http://www.nrc.gov/about-nrc/radiation/related-info/faq.html#2.
[66] Health Physics Society, http://hps.org/hpspublications/articles/RadiationTerms.html.

Appendix I: Abbreviations

^{60}Co	Cobalt-60
^{75}Se	Selenium-75
^{85}Kr	Krypton-85
^{90}Sr	Strontium-90
^{99}Mo	Molybdenum-99
^{131}I	Iodine-131
^{137}Cs	Cesium-137
^{147}Pm	Promethium-147
^{153}Gd	Gadolinium-153
^{169}Yb	Ytterbium-169
^{170}Tm	Thulium-170
^{192}Ir	Iridium-192
^{210}Po	Polonium-210
^{226}Ra	Radium-226
^{238}Pu	Plutonium-238
$^{239}Pu/Be$	Plutonium-239/Beryllium
^{241}Am	Americium-241
$^{241}Am/Be$	Americium-241/Beryllium
^{244}Cm	Curium-244
^{252}Cf	Californium-252
ALARA	As Low As Reasonably Achievable
AMedP-7.5(A)	*Allied Medical Publication 7.5 (A)*
AMedP-8	*Allied Medical Publication 8*
AMedP-8(C)	*Allied Medical Publication 8 (C)*

ARS	Acute Radiation Syndrome
BSA	body surface area
CBRN	chemical, biological, radiological, and nuclear
CONV	convalescent
CUT	cutaneous
DOW	died of wounds
	Defense Threat Reduction Agency
ERAD	Explosive Release Atmospheric Dispersion
FSU	Former Soviet Union
G-CSF	granulocyte-colony stimulating factor
Gy	units of gray
HoB	height of burst
HPAC	Hazard Prediction and Assessment Capability
IAEA	International Atomic Energy Agency
IDA	Institute for Defense Analyses
IND	improvised nuclear device
ITDB	Incident and Trafficking Database
KIA	killed in action
Km	kilometers
LIBN	light infantry battalion
NATO	North Atlantic Treaty Organization
NNSA	National Nuclear Security Administration
NRC	Nuclear Regulatory Committee
OSRP	Off-Site Source Recovery Program
RDD	radiological dispersal device
RED	radiological exposure device
RTD	return to duty

SCIPUFF	Second-order Closure Integrated Puff model
SME	subject matter expert
Sv	units of Sievert
TBq	terabecquerels
U.S.	United States
WB	whole body
WIA	wounded in action
DOE	U.S. Department of Energy
C	activity of concern

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13. SUPPLEMENTARY NOTES

14. ABSTRACT

This analysis describes the application of the NATO CBRN casualty estimation methodology to nuclear and radiological weapon threats. In the planning process, casualty estimates may influence the course of action selected, the flow of personnel into the theater, or the amount and timing of the medical assets moved into the theater. For illustrative purposes, the situation is that a commander has asked his staff to plan an operation by a light infantry battalion task force (LIBN). An alternative scenario is of a public event used to estimate the impact of the radiological or nuclear events on civilian populations. The basic nuclear challenge is a 10KT ground burst, with an alternative of a 10KT low air burst. The radiological challenge is an attack with 1.11x105 terabecquerels (TBq) of the radioisotope Cesium-137 (^{137}Cs). Alternative casualty estimates include ^{90}Sr; ^{241}Am, ^{238}Pu; and fallout. The casualty estimates varied from none to 100% of the population considered. When casualties were present, the numbers of casualties were such that they pose a considerable if not catastrophic operational problem. Further courses of action (such as countermeasure missions, unit dispersal and nuclear protective posture) should be considered to further mitigate nuclear or radiological weapons on the battlefield.

15. SUBJECT TERMS

radioisotope, radiation, chemical, biological, radiological, nuclear, CBRN, casualty estimation

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